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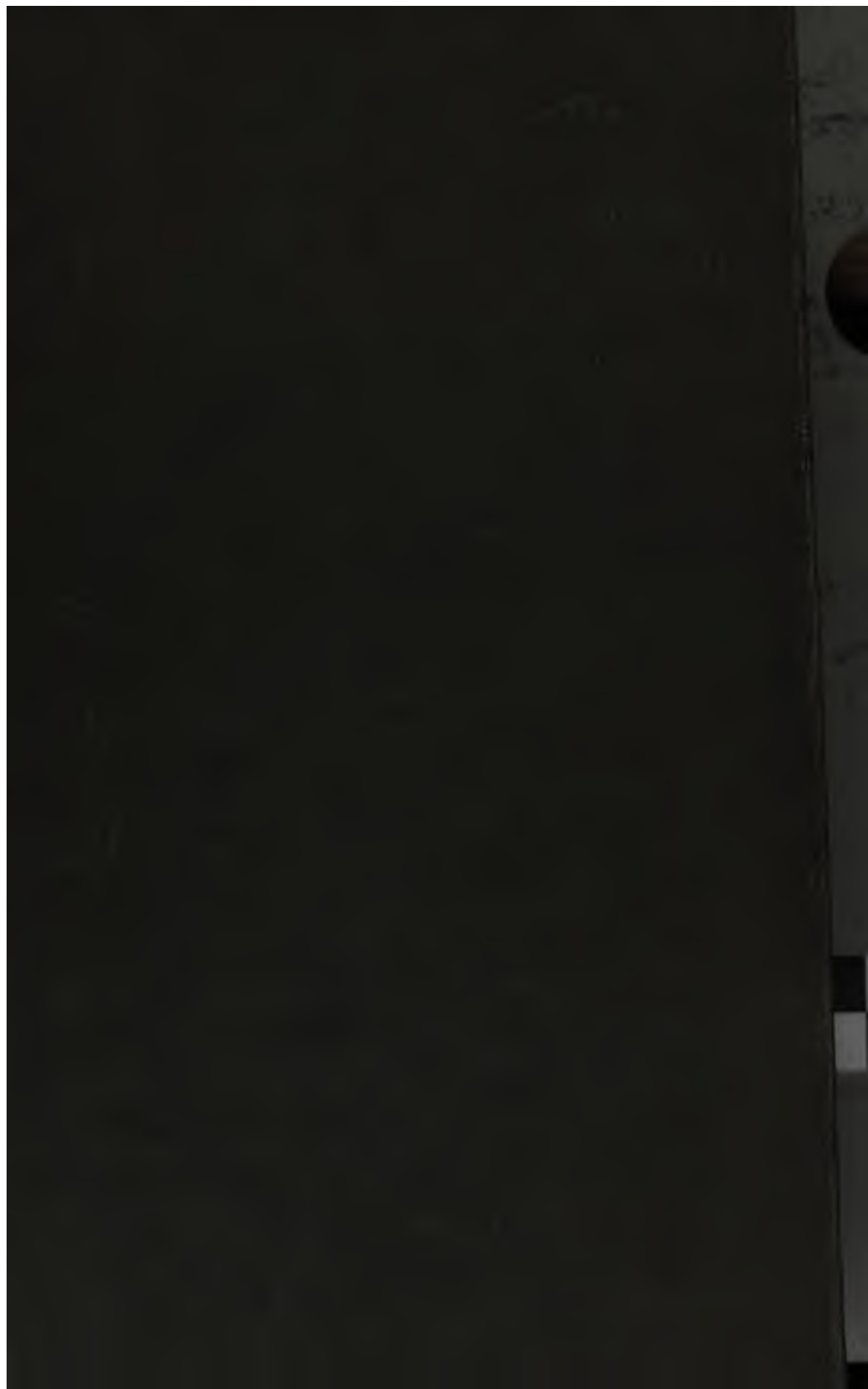
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# GENERAL PATHOLOGY

OR

THE SCIENCE OF THE CAUSES, NATURE AND COURSE  
OF THE PROCESSES OF DISEASE

BY

DR. ERNST ZIEGLER

PROFESSOR OF PATHOLOGICAL ANATOMY AND OF GENERAL PATHOLOGY  
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TRANSLATED FROM

THE TENTH REVISED GERMAN EDITION

(GUSTAV FISCHER, JENA, 1901)

AND EDITED

BY

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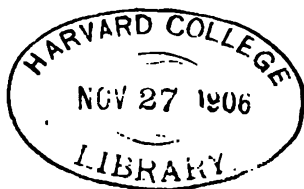
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**RUDOLF VIRCHOW**

**IN AUFRICHTIGER VEREHRUNG  
GEWIDMET**





## AUTHOR'S PREFACE TO THE TENTH EDITION.

---

**I**N the following pages of the tenth edition of my "Text-book of General Pathology and Pathological Anatomy" are to be found the results of two and twenty years of labor that has been but rarely interrupted. Since the first edition, which appeared in 1881, I have constantly endeavored to improve the book both in its contents as well as in its form; and I believe that I dare commit myself to the hope that in this edition there is offered a work which, within its assigned limits, presents the most important achievements of the nineteenth century in the field of general pathology and pathological anatomy in such a form as to meet the needs of the practising physician as well as of the student, who through the study of such would acquire a scientific foundation for practical medicine.

He who to-day looks back upon the results of medical investigation during the nineteenth century finds his attention involuntarily fixed upon that investigator who for the full half of the century just passed has been constantly active, and who through his scientific labors and his teaching has pointed the way to the knowledge of morbid processes, their nature and their origin; and in part has himself realized, and in part has paved the way and made possible the great advance of the past century in the domain of general pathology and pathological anatomy. Therefore it appears to me fitting in this year, in which the science of medicine of Germany and of the whole world is preparing to honor the eightieth birthday of its great master, Rudolf Virchow, to dedicate to him this book as a duty of gratitude. May he thereby learn that also those to whom it was not granted to sit as students at his feet have striven to build further upon the foundation laid by him, and have seen in him their master, to whom they are attached in gratitude and veneration.

---

In the revision of the new edition I have gone through each chapter with great care, and have supplemented, corrected, and extended the subject-matter according to the most recent literature and new investigations of my own.

The first three chapters have been completely worked over and reshaped, and I hope that by their new form and order the reader will be

enabled to orient the conditions there considered more easily than was the case in former editions.

In spite of the criticisms directed against certain portions of my presentation of inflammation and tumors I have not been led to make any changes touching the essential contents of these chapters. The attacks directed against these have inclined rather to strengthen my standpoint than to weaken it; although I have been induced, by changing somewhat the formulation of my views, to meet certain strictures which were caused more by the form of presentation than by the content itself.

Czerny's support of the theory of the parasitic nature of true tumors has not changed my view as to their etiology and nature, and if I have altered the phrase "*new-formation of tissue which is not caused by infection*" to "*new-formation of tissue apparently arising independently*," I have done so, as is shown by the subsequent text, not because of any doubt in the correctness of the former expression, but for the purpose of avoiding the criticism that such a definition might have a retarding influence upon investigations as to the etiology of tumors.

I have given especial attention to the revision of the chapters on Vegetable and Animal Parasites, and have enriched these with new and, I hope, instructive illustrations. It may be argued as to whether it is necessary in a text-book on general pathology to go so far into the separate forms of parasitic diseases as I have done; and whether it would not be better to be content with what is said in the first and third chapters upon Infection and the Resisting Powers of the Organism. For the acquiring of an understanding as to what an infection is and how the organism in general behaves toward it, the latter would probably suffice; but it appears to me to meet a pressing need that the student, after he has learned to recognize the pathological processes of life, should then be instructed more closely regarding the properties of the parasites causing the different infections, their manner of action upon the different tissues and the organism as a whole, and their mode of spreading throughout the body. For the elucidation of these conditions of so great importance to the physician I have provided this chapter with numerous illustrations, particularly the sections treating of *Streptococcus pyogenes*, *Staphylococcus pyogenes aureus*, and *Tuberculosis*, as well as those treating of the pathogenic *Protozoa*.

The bibliography has been brought up to the end of 1900, and I have endeavored in so far as possible to cite those investigations which are adapted to facilitate and advance scientific research in the given field. Since such collections of the literature as may be easily utilized are wanting, I believe the bibliography given has met a pressing want, and I have already had the satisfaction of knowing that this has been recognized on various sides.

I cannot neglect to remember with gratitude in this edition the pub-

lisher, Dr. Gustav Fischer. To the excellent form which he has given the book in all the editions is owing a large part of its success. His friendly and obliging spirit has made it possible to provide the book with such illustrations as are suitable to explain and to amplify that which is described in the text.

**E. ZIEGLER.**

**FREIBURG IM BREISGAU, April, 1901.**



## TRANSLATOR'S PREFACE.

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**I**N the translation of the tenth edition of Ziegler's "General Pathology" the endeavor of the translator has been to render the text and spirit of the original in a simple and consistent English form, suitable to the needs of the medical student and reader. He has refrained from alterations of the subject-matter, and has made but few additions, the latter being only of such a nature as to adapt certain statements made in the text the better to their American environment. The dedication of the German edition to Virchow has made the book in a certain sense a Virchow "Festschrift"; and it seems especially fitting that it should contain the bibliography of the most important achievements of the past half-century in the domain of pathology and pathological anatomy. The bibliography of the earlier editions was omitted in the previous translations, but in the present translation the complete bibliography, as given by Ziegler, has been included. In addition the editor has inserted some of the most important American references, particularly those of the last several years. He has not in any measure attempted to make a fully representative American bibliography, but has chosen those references which he has found of most service in his teaching. It is not necessary here to emphasize the teaching value of such a bibliography as given in the present volume. In the study of a science in which such great advances are almost daily made, and in which the point of view changes at a corresponding rate, it seems essential that the student, in addition to a thorough grounding in the established principles, should be given also a broader view of the development and solution of pathological problems.

ALDRED SCOTT WARTHIN.

ANN ARBOR, MICHIGAN, September 1st, 1903.

NOTE.—Because of the difference in the size of the page it has been found necessary to reduce slightly some of the illustrations. In such cases the magnification or amplification has been changed to meet the amount of reduction.



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# GENERAL PATHOLOGY.

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## INTRODUCTION.

**General Pathology**, the **science of disease**, has for its especial province the *investigation, from all sides, of the processes of disease, the determination of their nature and significance, their causes and origin, their course and termination.*

The life of an organism reveals itself by means of certain peculiar activities which we regard as the *manifestations of life*. In the case of unicellular organisms these manifestations consist chiefly of changes of form, movement, and division of cells, the taking-up of food and the giving-off of waste products; the last-named processes being visible under the microscope in the case of formed material, but in the case of soluble substances they are revealed by changes in the chemical composition of the medium in which the cells complete their existence. In multicellular organisms, particularly in the more highly developed mammals and in man, these vital functions are much more varied and complicated. In the general metabolism of the organism a very great variety of tissues and organs takes part: the intestinal tract, the respiratory apparatus, the blood, and glands of different structure, some especial individual function being assigned to each. Reproduction is accomplished by means of special organs and apparatus. Motion is dependent upon special tissue formations. The perception of external influences is made possible through highly developed sense-organs, and the entire organism is controlled by a complicated nervous system, the functions of which are so individual and many-sided as to render their study extremely difficult. The investigation of the normal processes of life, which falls to the province of *physiology*, is accordingly very difficult and complicated, and we are yet far from an exact knowledge of all the processes of the healthy or normal life.

The **study of disease-processes**, as well as of the normal, takes its departure from the life-manifestations of the human body, and *such individuals are regarded as ill whose functions in part deviate from those recognized as normal.* The **science of general pathology**, whose exposition forms this study, is, accordingly, first of all to be designated as **pathological physiology**; that is, the science which seeks to recognize the significance and character of the manifestations of disease. It can, however, do justice to this task only when it at the same time determines also the anatomical changes which give rise to disturbances of function in tissues and organs, the causes which produce them, and their mode of origin; that is, the **pathological anatomy**, the **etiology**, and the **pathogenesis** of the processes of disease are essential parts of general pathology.

Every manifestation of life is dependent upon a material substratum,

every form of vital activity presupposes some special condition of this substratum, and physiology teaches us that the individual functions of tissues and organs are dependent upon the special structure of their individual organization. A change of function in this or that direction presupposes also a change in the tissue or organ, and experience teaches that such changes in reality take place; and, further, that for the same a *causa efficiens* may at times be demonstrated. It is to be noted, however, that the tissue-lesion underlying a disturbance of function cannot always be discovered, nor is it always possible to ascertain the etiology or pathogenesis of the same; but the number of such cases is constantly diminishing through the improvement of our methods of investigation, as afforded by means of modern microscopical technique, animal experimentation, and the utilization of chemical research; and this number is already reduced to a small percentage of pathological processes. The experienced physician is, therefore, enabled from given symptoms of disease to diagnosticate certain organic changes; and, further, from the same to recognize often the causes of the disease and the manner of its origin.

The symptoms of disease may at one time point to a certain organ as the seat of disturbance, or at other times the organism as a whole may appear to be involved; we may distinguish accordingly **local** and **general diseases**. Not rarely a number of organs may be affected at the same time—this may be spoken of as **multiple localizations** of disease; or in other cases the disease may have a **localized seat**, but runs its course with such changes of tissue that a **diseased condition of the entire organism** results.

The specific grouping of pathological symptoms which repeats itself in many cases makes it possible for us to distinguish **different forms of disease**, and occasionally the physician finds it difficult in a given case to determine the exact form of the disease. As criteria for the origin of different types, the especial *causes* of the disease, the *location* of the tissue-lesion, and the *nature* of the process are to be considered. There results, therefore, a great variety of disease-pictures; and it is not always easy, often impossible, to determine either the seat of the disturbance, the character of the tissue-lesion, or the causes leading to the same.

The duration of different diseases is very variable, and we may therefore distinguish **acute**, **subacute**, and **chronic** processes, the last extending through years or even decades. An illness may terminate in **recovery** and **cure** or with the **death** of the affected individual. A cure is assumed when all symptoms of disease have vanished, but experience teaches that the complete restoration of the affected part often takes place much later than the disappearance of the symptoms. Not infrequently healing is delayed and the disease becomes **latent**; that is, extensive tissue changes remain, the injurious agent is not removed from the body, though symptoms of the disease are no longer present. For example, the symptoms of a tuberculous affection may completely disappear, though foci containing tubercle bacilli are still present in the body from which by chance a further extension of the disease may take place, and, accompanying this, new symptoms may arise.

When in the course of a disease a local loss of tissue is not replaced by the process of healing, a **defect** remains; a defect of large size, on the visible external portions of the body, such as the loss of a finger or leg, is spoken of as a **mutilation**.

If, in the place of a highly organized tissue which has been destroyed,

connective tissue of a lower grade is formed, or if an external defect is closed by such formation of tissue, there results a **scar**. When, as the result of some disturbance of the normal intra-uterine development, certain tissues at birth present pathological alterations, the condition is designated as a **congenital malformation** or **anomaly**. If the affected organs show functional disturbances, the condition may be termed a congenital disease.

*The broad field covered by general pathology necessitates a narrowing of its subject-matter; and it happens conveniently that a part of pathological physiology, which may be designated clinical pathology, is best relegated to study at the bedside, to special courses and lectures, or to text-books. The disturbances of function pertaining to the different organs and systems, heart, nervous system, organs of special sense, respiratory tract, urinary apparatus, digestive tract, etc., cannot be discussed in this connection.*

*A detailed consideration can be undertaken only of those phenomena of disease which are consummated in the elementary constituents of the tissues, the tissue-cells and the intercellular substance; and these can be judged and properly valued only through an exact study of the anatomical and histological changes thereby presented. General pathological anatomy becomes, therefore, the indispensable foundation for general pathology; but it leads to a complete knowledge of the processes of disease only when at the same time the etiology and pathogenesis of the tissue-lesion are revealed in a satisfactory manner.*

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## CHAPTER I.

### The Extrinsic and Intrinsic Causes of Disease.

#### I. The Origin of Disease through Extrinsic Causes.

1. *Origin of Disease through Deficient Supply of Food and Oxygen, through Fatigue, Heat and Cold, Changes of Atmospheric Pressure, and Electrical Influences.*

§ 1. From his birth to his death man is constantly exposed to the influences of the world surrounding him, many of these external influences being favorable to the normal exercise of his functions, while others are unfavorable.

As long as the human organism is able to offset these influences, through independent changes of its relations to the external world or through adaptation of its functions to external conditions, it will remain in health. If his regulating mechanism no longer suffices for successful opposition to unfavorable external influences, and if he cannot escape these or change his conditions of life, man becomes ill or dies.

For its preservation the body needs first of all a certain amount of food, water, and oxygen; and though it may exist for a short time without these, an **insufficient supply of oxygen, food or water** beyond a certain limit and after a certain time must of necessity lead to disease or death.

A **total deprivation or diminution of the supply of oxygen** to the tissues may take place at any period of life, either because of a lack of oxygen in the surrounding medium, or some obstruction to the entrance of the oxygen of the air into the lungs or blood, or inability on the part of the blood to take up a sufficient amount of oxygen. The *fœtus in utero* may be insufficiently supplied with oxygen as a result of diminished supply to the mother, premature separation of the placenta, disease of the placenta, or compression of the cord, whereby the interchange of gases between the maternal and foetal blood is hindered. After birth an insufficient supply of oxygen may be due to hindrances to respiration, or the child may be so weak that its respiratory movements are insufficient to expand the lungs.

When the supply of oxygen is completely shut off, as may happen from the entrance of water or other fluid into the respiratory tract or from closure of the air-passages, the affected individual dies in a very short time from **choking or suffocation**. Animals confined in closed chambers die as soon as the oxygen of the air reaches two or three per cent by volume, the normal volume percentage being 20.8 (Cl. Bernard, P. Bert).

If the supply of oxygen is not wholly shut off, but only greatly diminished, as in the case of carbon-monoxide poisoning, in which the firm combination of carbon monoxide with the hæmoglobin prevents the taking up of oxygen by the red blood-cells, death by suffocation may

take place only after several days. In gradually increasing hindrances to the entrance of oxygen and resulting accumulation of carbonic acid in the blood, as in cases of narrowing of the lumen of the larynx through inflammatory exudates, compression of the trachea from goitre, weakening or obstruction of respiration, etc., a condition of breathlessness, cyanosis, convulsions, and disturbances of consciousness is produced, which is termed **asphyxia**.

If the taking up of oxygen is diminished in only a slight degree but for a long time, as in the case of a lessened number of red blood-cells in oligocythæmia, degenerative processes characterized by increased destruction of albumin and by fatty changes may occur in the tissues and organs, and these may lead not only to disease but under certain conditions to death.

**Total deprivation of food and water** leads to a rapid loss of body-weight, inasmuch as the fat and albumin continue to be decomposed; death finally ensues. According to Lehmann, Müller, Munk, Senator, and Zuntz, the total amount of oxidation in cases of starvation does not fall below that of the same individual in the fasting state under the same conditions. A marked decomposition of albumin and loss of water take place. In animals death occurs after the loss of about forty per cent of the body-weight, about one-half of the loss being due to the waste of muscle.

The fat disappears most rapidly; even as much as ninety-three per cent may be lost. The other organs show diminution of substance in the following order: liver, spleen, testicles, muscles, blood, intestines, skin, kidneys, and lungs. The heart, nervous system, and bones show the least loss of weight; but, according to the researches of Lehmann, Müller, Munk, Senator, and Zuntz, destruction of bone-tissue takes place during starvation, as is shown by the increase of calcium and phosphoric acid in the urine, following ingestion of water. In the blood there is a rapid diminution of the leucocytes (Luciani); the red blood-cells, on the other hand, may be relatively increased in number. The organs of animals dying from starvation show simple atrophy of the tissue-elements, particularly of the liver (Lukjanow), hyperæmia, scattered hemorrhages, degenerations, and inflammatory changes, especially in the intestine, liver, kidneys, and nervous system.

In the case of total deprivation of food and water, death occurs in man after from seven to twelve days; bodily exercise hastens the end, ingestion of water may delay it markedly, so that some individuals have been enabled through the use of water to endure a period of total abstinence from food for thirty days or longer, without dying or suffering permanent harm. The consumption of water leads to an increased excretion of nitrogen in the urine.

Life may be maintained for a long time upon insufficient nourishment, but a wasting of the body takes place which may lead to a condition of extreme emaciation, *marasmus*, or *cachexia*, and finally to death. The same thing happens when the composition of the food is unsuitable and only a portion of the necessary food-elements is present in sufficient amount, so that the body is starved either in albumin, fat, salts, or water. Dogs deprived of all nitrogenous food die in from thirty-one to thirty-four days (Magendie). When the food is abundant but poor in albumin, there occur after a time (in dogs after six weeks) loss of appetite and repugnance toward the proffered food, with impairment of digestion and assimilation (Munk). This is especially the case when the food

is lacking in fat, less so when albumin or the carbohydrates are wanting. It is very probable that the lessened absorption is chiefly due to diminished secretion of the digestive juices, this being capable of quantitative demonstration in the case of the bile. The fæces are finally nearly destitute of bile.

An insufficient supply of *iron* for a long period gives rise to anæmia and general disturbances of nutrition.

If for experimental purposes an animal well supplied with food is **totally deprived of water**, there is a rapid loss of body-weight followed in from eight to twelve days by death. The pathological changes found in the different organs are similar to those resulting from starvation. They are caused partly by lack of water and insufficient absorption of food, and partly by the retention of harmful products of metabolism.

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§ 2. An **unusual demand** upon the **functional activity** of an organ for an **extended period of time** leads sooner or later to a state of **exhaustion**, which is, in part, due to the consumption of cell-substance,

and in part to the formation of toxic products of metabolism, whereby the organ is incapacitated for further extended activity. Most often the **results of overwork** are manifested in the muscles and nervous system in the form of such symptoms as soreness and stiffness of the muscles, mental excitement, sleeplessness, heavy feeling in the head, loss of appetite, great weakness, unnatural sweating, and sometimes fever. Overwork of the heart leading to exhaustion may cause death. This may occur either when the heart is for a short time taxed to the extreme limit of its power or when for a longer period it works slightly under its maximum capacity. If the exhausted tissues are permitted to rest and supplied with an abundance of nourishment, the loss of cell-material due to the excessive activity will be replaced, the products of metabolism, which are hindering the functional activity of the tissue, will be removed, and the part restored to its normal condition.

If a tissue is frequently subjected to excessive functional demands, and if the periods of rest are too short to admit of its complete restoration, there will result ultimately a condition of permanent functional insufficiency, a chronic exhaustion, which may under certain circumstances manifest itself in a degeneration or atrophy of the affected organ. For example, a muscle through overwork may become atrophic, and a brain too constantly stimulated to activity without proper periods of rest may finally reach such a state of weakness and exhaustion that it is incapable of performing even its normal function. Through rest and properly regulated nourishment such a brain may recover; but beyond a certain limit of exhaustion the functional insufficiency may become permanent and eventually manifest itself in anatomical changes.

A very severe over-stimulation of the nervous system, even for a very short time, may under certain conditions lead to a paralysis of its functions, which, in case the heart and respiratory apparatus are affected, may cause death, but in the majority of cases is of a transitory nature.

Overwork of any organ is more quickly followed by fatigue and functional insufficiency in the case of impaired nutrition. Fatigue and insufficiency of the heart are most frequently observed when the general nutrition is lowered, as in cases of fever, or when there is deficient oxygenation of the blood, as in poorly compensated heart lesions or pulmonary diseases.

It is very probable that overwork lowers the resistance of the body to various infections.

When the functional demands upon a muscle or gland are only moderately increased, and if the nutrition is good and in proportion to the increase of labor, the **affected tissue becomes hypertrophied**, and is thereby enabled to perform the increased work permanently.

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§ 3. **High temperatures** may act, either through *local destruction of tissue (burning)* or through *overheating of the entire body*. The latter condition is possible only when the body is exposed to an increased temperature for such a time that it cannot protect itself from overheating by increased heat-dispersion. In dry air of from 55–60° C. (131–140° F.) the most profuse perspiration is no longer able to protect the body permanently from overheating, and in a moist atmosphere the same is true at even lower temperatures.

If rabbits are placed in well-ventilated incubators at a temperature of 36–40° C. (96.5–104° F.), their body temperature will rise to 39–40° C. (102.3–104° F.), the respiration and pulse being at the same time greatly increased in frequency. A very marked elevation of body temperature may lead in one to three days to death through paralysis of the nervous and muscular systems, the chief symptoms being a marked increase of both respiration and heart's action. If the increase of body temperature is not greater than 2–3° C. (3–5° F.), the animals may, if properly nourished, live from ten to thirty days or even longer, but they will lose in weight and ultimately die, showing before death a gradually increasing diminution of hæmoglobin and of red blood-cells. Degenerative changes, particularly fatty degeneration, occur in the liver, kidneys, and heart-muscle. During the experiment there is an increased production of urea.

If the human body is subjected to high temperatures, it may become overheated, and the condition known as **heat-stroke** may result. The pulse-rate is increased, the respiration very rapid and labored, the pupils are dilated, and finally death may occur as in the case of the animals made the subject of experiment. The occurrence of heat-stroke is favored by heavy bodily labor, interference with heat-dispersion through impermeable clothing, or by a lack of water in the body.

The direct action of the rays of the sun upon the head may cause cerebral and meningeal irritation, a condition characterized by hyperæmia and inflammatory exudations, and known as **sun-stroke** or **insolation**.

The local effects of heat upon the skin, **burns**, are, according to the intensity of the heat and the time of its duration, either hyperæmia (burn of first degree), formation of a blister (second degree), tissue-eschar (third degree), or carbonization (fourth degree). The heat produces local changes in the tissues, and kills them at a certain height of temperature or after a certain time of exposure to its action.

When a large part of the surface of the body, about one-third, is burned, the affected individual usually dies, even though the burn is only of a slight degree and eschars are not formed. This phenomenon has been explained in various ways. Billroth, Foà, Mendel, and others believed the cause of death to lie in a suppression of perspiration and the resulting accumulation of toxic substances in the blood; while others, as Sonnenburg and Falk, sought the cause in a reflex lowering of vascular tone. In the foudroyant cases, according to Sonnenburg, the overheating of the blood causes paralysis of the heart. Ponfick, Klebs, von Lesser, and others, on the other hand, are of the opinion that the fatal issue is due to injury and destruction of the red blood-cells. Silbermann, Welti, and Salvioli also seek the cause of death in an injury to the blood, emphasizing, however, not so much the destruction of the red cells as the occurrence of stasis and coagulation of the blood in the vessels of different organs, which are interpreted as resulting from the changes in the blood. On the other hand, Kijanitzin and Parascandolo hold that there is formed in the bodies of burned individuals a poison (ptomain) which has an injurious effect upon the nervous system.

The anatomical findings in fatal cases of superficial burns would indicate, when death has not resulted very quickly from the severe shock to the nervous system and the overheating of the body, that the cause of death is to be sought in the changes in the blood and in disturbances of the circulation. The blood-changes consist in destruction of the red blood-cells, or in such injury to them as to diminish their function and to give rise at the same time to a deposit of the products of destruction and of hæmoglobin in the liver, spleen, and kidneys. The changes are further characterized by a tendency on the part of the blood to stasis and intravascular coagulation, through which vessels of both the pulmonary and the systemic circulation may be obstructed. In this connection should be mentioned also the fact that both during life and after death venous stasis and hæmorrhages, as well as arterial anæmia, are occasionally observed, and that local tissue-degenerations and necrosis may occur in certain organs, as, for example, in the kidneys, liver, mucosa of the stomach and intestine, bones, and soft parts.

**Low temperatures** act in the same manner as high ones, in part through local injury and death of tissues, in part through refrigeration of the entire body. Severe and lasting lowering of temperature causes tissue death; after mild chilling there occur, as the result of tissue-degeneration, thrombosis, hyperæmia, and exudations which are relatively rich in leucocytes. A very short refrigeration at the freezing-point is sufficient to produce degenerative changes which are quickly followed by regenerative proliferation on the part of the cells remaining uninjured. Epithelial thickenings may be produced (Fuerst) by repeated slight refrigerations (as well as by repeated slight increase of temperature). The tips of the extremities, nose, and ears are the most easily frozen. After repeated chillings of mild degree inflammatory redness and swelling of the skin, associated with severe itching, often occur (*chilblains*, *perniones*).

If the temperature of the entire body be markedly lowered, a condition of general paralysis results from the diminished excitability of the tissues, the nervous system and heart being especially affected. The sensorium becomes dulled, the heart-beat and respiration gradually grow weaker, and finally cease entirely. If the body be again warmed, before the excitability of the tissues is wholly lost, the power of movement

in the limbs is gradually restored, and after a time consciousness returns. In man, instances of complete recovery have been observed, even after refrigeration of the body to from 24–30° C. (75–86° F.).

Besides the more severe forms of local or general lowering of the tissue temperature there may occur, as harmful pathogenic influences, mild general or local chillings, the so-called **colds**, as the result of which disease-phenomena may manifest themselves partly at the seat of chilling, partly in organs in distant parts of the body. For example, after widespread refrigeration of the skin there may occur diarrhoea, catarrh of the respiratory tract, or disease of the kidneys; after local chilling of the skin, painful affections of the deep-seated muscles. The exact relation between these phenomena and the refrigeration is unknown (the oft-repeated hypothesis that they are due to hyperæmia of the internal organs caused by the chilling of the body-surface has not been proved), but there is no reason on this account to deny the existence of diseases caused by cold. Though many diseases formerly attributed to “catching cold” have been shown to be of infectious origin, there yet remain a number of diseased conditions for which we know no other etiology than that of refrigeration. Conditions of the body in which the skin is hyperæmic and the perspiratory function active favor the taking of cold. Many individuals appear to possess a predisposition on the part of certain tissues to the effects of refrigeration; in one person certain muscles, in another the mucous membranes will be affected.

According to the view of many writers, refrigeration of the body increases the susceptibility to infection, so that, for example, the pathogenic bacteria which may be present in those cavities of the body accessible from without may, after such refrigeration, be able to exert their injurious influences upon the tissues.

According to *Pflüger* and others, all the vital processes may be brought to a standstill through refrigeration, without its being impossible for a recovery to take place from the apparent death. This may happen even when the animal is frozen to a solid mass. *Preyer* also holds the opinion that the continuity of life may be wholly interrupted by refrigeration, and designates subjects who are thus “lifeless,” but still capable of living, as *anabiotic*. Frogs are said to remain capable of life for many hours even though the temperature be reduced to –2.5° C., at which temperature the heart is frozen. According to the investigations of *Koch*, such anabiosis of solidly frozen animals is possible when only a portion of the water contained in the body of the animal is frozen and when the thawing process takes place slowly. In the case of rapid thawing strong diffusion currents are set up between the water coming from the ice-crystals and the concentrated albuminous solutions of the blood and the tissues; and these currents may exert a damaging effect upon the latter.

According to the investigations of *J. Dewar* (*Proc. of the Royal Soc.*, London, 1900), the seeds of wheat, barley, mustard, peas, and pumpkins do not lose their germinative power when put into liquid hydrogen; that is, in a temperature of –250°. Further, the protoplasm under these conditions was not changed by the cold.

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§ 4. A sudden **lowering of atmospheric pressure**, as in the case of mountain-climbing and balloon ascents, may cause conditions of great exhaustion, with marked palpitation of the heart, unconsciousness, irregular breathing, and sometimes vomiting, and bleeding from the gums and lips. These symptoms depend most probably upon a *lack of oxygen* (P. Bert), the capillaries of the lung being unable to take up sufficient oxygen from the highly rarefied air. According to the investigations of Schumburg and Zuntz, it appears that a given amount of labor calls for a greater amount of oxygen at an increased elevation than at a lower level. The symptoms of mountain-sickness appear at a lower elevation than those of balloon-sickness, owing to the demands made upon the muscles in the former case during the climbing. During the building of the Gorner Grat Railway it was found that at a height of 2,700–3,000 metres the capacity of the laborers was diminished to a third. The occurrence of hæmorrhages is probably due to the formation of fissures in

the mucous membranes, caused by drying due to the rapid evaporation (Hoppe-Seyler, von Recklinghausen).

According to the researches of Egger, Miescher, and others, a sojourn in high altitudes leads, after a short time, to an increase in the number of red cells and a greater hæmoglobin-content of the blood.

Schaumann and Rosenquist hold that the same phenomenon may be observed in animals confined for some time in bell-jars at a lower atmospheric pressure. Other authors (Schumburg, Zuntz, Gottstein) oppose this view, and maintain that the phenomenon is due either to a thickening of the blood from loss of water and to changes in the distribution of the blood, or to changes in volume of the measuring-apparatus; they endeavor to explain the favorable effects which many individuals experience from a residence at high altitudes by certain stimulating influences (greater exposure to sun's rays) which affect the nervous system and cause increased metabolism. According to Marti, *intense and prolonged irradiation* of the body stimulates the formation of red blood-cells and to a lesser degree also that of the hæmoglobin.

A sojourn in diving-bells or caissons, such as are employed in building operations beneath the water, in which the **atmospheric pressure is increased**, under certain conditions, as high as four atmospheres or even greater, causes a slight difficulty in breathing and a relatively unimportant increase of the pulse-rate. If a change be made quickly from the compressed atmosphere to air of ordinary pressure, there may occur within an hour a condition of great fatigue, tightness of the chest, ringing of the ears, cramps in the muscles, pains in the joints and limbs, hæmorrhages from the nose, ears, and lungs, dilatation of the pupils, and under certain conditions paralysis, coma, delirium, and even death after an interval of from one to twenty days. The cause of these phenomena is probably to be found in the sudden escape from the blood of nitrogen which had been absorbed under the high pressure (von Leyden), or in an obstruction of the blood-vessels of the spinal cord through the formation of gas-bubbles (Hoche). According to experimental investigations of Heller, Mager, and von Schrötter, the blood, after rapid removal of pressure, contains free gas (almost exclusively nitrogen), so that free gas circulates in the blood. The researches of von Leyden and von Niki-foroff show that in fatal cases associated with paralysis areas of degeneration are found in the white columns of the spinal cord, in which individual nerve-fibres are torn apart, presenting marked changes in the form of swelling of the axis-cylinders, disintegration of the medullary sheaths, and the formation of vacuoles in the place of the nerve-fibres. These disturbances are regarded as due to the production of gas-bubbles within the spinal cord. If the gray matter is involved, the ganglion-cells may also degenerate.

Changes in the electrical condition of the atmosphere and in the magnetic state of the earth produce no demonstrable changes in the human body; on the other hand, **electric discharges**, as lightning-stroke, may cause, in part, local burns (Fig. 1), and, in part, lesions of the whole body. Under certain circumstances lightning-stroke causes laceration of internal organs, as, for example, of the heart and liver. The most frequent and important effect of lightning-stroke is a **paralysis of the nervous system**, which gives rise to a severe dyspnoea, which may be fatal after a few minutes or hours or which may gradually pass away after several hours, days, or weeks. Only rarely do individual nerve-trunks remain permanently paralyzed. A transitory paralysis may oc-

cur when the electrical discharge has not passed through the body but has descended in its neighborhood.

In individuals who have been struck by lightning there may be found slight or severe burns of the skin corresponding to the points of entrance and exit of the current, and various injuries to the tissues in the course of its path through the body. The marks of the burn are for the greater



FIG. 1.—Lightning-figures on the shoulder, breast and arm of a woman struck by lightning.

part red, and form peculiar branching zigzag lines, the so-called *lightning figures* (Fig. 1), which are essentially a hyperæmia, and soon disappear if the burns are not severe.

The passage of **powerful electric currents of high tension**, such as are generated by dynamos, through the human body, as may happen when an individual is placed in a circuit or comes into contact with an uninsulated conductor, may give rise to severe disturbances or cause death. According to Kratter, the lower limit of danger occurs at a tension of about five hundred volts. Alternating currents are much more dangerous than continuous ones of the same strength and tension. When the effects are not fatal, the injured person is suddenly rendered unconscious, this condition lasting for a few minutes or several hours, and for several days afterward symptoms of vertigo, prostration, headache, and palpitation of the heart

may persist (Kratter). At the points of contact more or less severe burns are produced.

In fatal cases, death takes place suddenly or rarely after ten or thirty minutes. The autopsy findings, aside from the burns at the points of contact, are evidences of suffocation and hypervæmosity of the blood, stasis of the blood within the thoracic vessels, and often small scattered hæmorrhages which are due partly to suffocation, and partly to the direct action of the current. The cause of death is paralysis of the centre governing the respiration or the heart's action.

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2. The Origin of Disease through Mechanical Influences.

§ 5. **Traumatic influences of various kinds leading to concussion, bruising, and laceration of tissue** are of very frequent occurrence, and act partly through the tearing and destruction of tissue, partly through changes in tissue-organization not recognizable to the naked eye, and partly through lesions and ruptures of the blood- and lymph-vessels, and through irritation and paralysis of nerves. The sequelæ are partly *necrosis* and *destruction* of tissue, partly *disturbances of circulation, inflammation, and regenerative proliferations*. Frequently repeated *mechanical traumatisms of slight degree, such as rubbing*, may give rise to *congestive hyperæmia and inflammations*, which may lead further to *hyperplastic growths of tissue*. If large quantities of *insoluble dust particles* are continuously taken into the lungs, extensive changes may occur in these organs and, under certain circumstances, in other organs. As a result of prolonged *pressure and diminution of space*, atrophy of an organ or tissue may occur (corset-liver).

After a single or after frequently repeated trauma, there may develop under certain conditions at present unknown to us, malignant new-formations of tissue called *tumors*. Trauma may further pave the way for an *infection*, either in that the wound caused by the trauma is *infected at the time of injury or is secondarily infected from without*; or that *micro-organisms were previously present* in the body under conditions inhibiting their growth, and these find in the *injured tissues a suitable soil for growth*, so that to the trauma an infection is joined.

**Traumatic influences** affect, first of all, the **external parts of the body**; but it may happen, either with or without visible injury to external parts, that **internal organs** may be injured, and the internal lacerations, necroses, and hæmorrhages thus produced may be followed, not only by inflammations and reparative tissue proliferations, but also by malignant neoplasms (as, for example, after fractures of bones), and by infective processes.

Mechanical lesions (also thermal, electrical, and corrosive) run a special course, if through the local injury the **nervous system** becomes involved. Such involvement occurs either through the direct action of the trauma upon the central nervous system; or, by the stimulation of the sensory or sympathetic nerves, the central nervous system may be so affected that a number of additional nervous symptoms follow.

If the direct concussion of the cranium is followed by paralysis of the cerebral function and unconsciousness, the condition is termed **commotio cerebri** or **cerebral concussion**. This term is especially used when the trauma has produced no visible changes in the structure of the brain, or at least none of any size or importance.

Excessive stimulation of the peripheral nerves may cause a reflex inhibition or paralysis, involving chiefly the functions of the heart and respiratory apparatus; the symptoms thus produced being collectively designated as **shock**. The most frequent causes of shock are injuries to the spinal column, abdominal cavity, and scrotum, less frequently to the extremities and thorax. Further, shock may be caused by lightning-stroke, burns, corrosions of the skin, fear, and psychical emotion through whatever avenue of perception they may be called forth. In individuals whose nervous systems are in a certain condition of excitement are especially liable to shock; conditions of narcosis and drunkenness inhibit its occurrence.

Shock is characterized chiefly by weakened energy on the part of the heart and irregular breathing, which lead to a decrease in the interchange of gases in the tissues and to a lowering of the temperature; as result, the venous blood in persons dying of shock is lighter in color than the normal venous blood (Roger). The consciousness is usually preserved, the skin and visible mucous membranes are pale, the pulse is small and markedly quickened, often irregular and intermittent. Further, the individual suffering from shock may be either excited, groan, shriek, and complain of a fearful anxiety associated with dyspnoea (*erethistic shock*); or he may lie quiet, with sunken countenance and exhibit evidences of great weakness of both sensory and motor functions (*torpid shock*). In severe cases death takes place from the stoppage of the heart and cessation of respiration.

Shock, in being due to the over-stimulation of the peripheral nerves is closely allied etiologically to the phenomenon known as **syncope**; but the last-named condition differs essentially from shock in that its chief symptom is a transitory loss of consciousness, while the functions of the heart and respiration show no marked disturbance. Syncope is, further, usually preceded by prodromal symptoms, such as dizziness, ringing in the ear, and darkening of the visual field, these being absent in shock.

Not infrequently, following an injury to some part of the body, there may arise a more or less pronounced functional disturbance of the nervous system, which may often persist long after the local injury has healed, so that such disturbance is in no way dependent upon anatomic changes in the peripheral or central nervous system, but must be r

garded as a *purely functional disturbance of psychical origin*. Such conditions are termed **traumatic neuroses** or **accident nervous diseases**, and are characterized chiefly by subjective but in part also by objective symptoms. To the first belong especially pains not definitely localized at the seat of injury, as headache, pain in the chest, backache, difficulty in movement, general lassitude, inability to perform mental labor, dullness of perception, disturbances of sight, flashes before the eyes, dizziness, restless sleep, loss of appetite, and disturbances of digestion. With these last symptoms are associated (Oppenheim, Strümpell) psychical depression of a hypochondriacal or melancholic character, irregularly placed areas of cutaneous anæsthesia, enfeeblement of the senses of taste, hearing, and smell, motor paralysis, cramps, and hyperæsthesia, concentric narrowing of the visual field, pareses, muscular spasms, tremors, acceleration of the pulse, and tendency to sweating.

According to the opinion of various writers, these phenomena depend essentially upon a psychical shattering of the perceptive life, a **psychoneurosis** which is less often due to the trauma and the associated psychical shock than to the resulting anxiety over health and business matters. The condition in part partakes of the nature of *hysteria*, as characterized by a disturbance of the normal relation between the mental and bodily processes; in part of *hypochondria*, as recognized by the spontaneous occurrence of abnormal sensations; and in part of a *neurasthenia*, which reveals itself by the production of abnormal pathological sensations through slight stimulation or exertion. If the will no longer controls the motor centres, hysterical paralyses arise; if the normal control and inhibition of the will are lost, so that unreasonable will-stimuli are created and influence the muscles, hysterical twitchings, contractures, or convulsions take place. If a nervous stimulus arising in the sensory tract fails to reach the consciousness, there follows a hysterical anæsthesia; if there arise in the consciousness the images of expected or feared sensations, and if these images are intensified into actual subjective stimuli of consciousness, hysterical pains and neuralgias result (Strümpell).

Rosenbach designates as **kinetoses** those diseases which arise when energetic and continuous movements of the body in one direction are changed into the opposite direction, so that a shifting of the internal organs results. In this class belong the pathological phenomena observed in *seasickness*, and in the conditions caused by *see-sawing*, *whirling*, *movement in a vertical direction*, and *sudden stoppage of motion*. As a result of the rapid change in direction of bodily motion, the molecules which are moving in the line of the primary direction are forced to move in the opposite direction; and, according to Rosenbach, such a change is sufficient to cause more or less important molecular disturbance. He explains the symptoms of seasickness, as, for example, the abnormal secretion of the stomach, the increase of intestinal peristalsis, the vomiting, etc., as the results of purely mechanical influences on the tissues, and believes that the liver, intestine, brain, and nerve-plexuses are similarly affected through mechanical influences acting upon their protoplasm. Further, purely psychical influences excited by feelings of discomfort may aid in the production of seasickness, just as disgust, fright, or fear may cause dizziness.

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### 3. The Origin of Disease through Intoxication.

§ 6. By **poisoning** or **intoxication** is meant that *impairment of health, caused by the injury to a tissue, which certain substances, by virtue of their chemical nature, are able to produce under certain conditions.* Such substances are termed **poisons**, and are derived partly from the mineral kingdom, partly from the vegetable, and partly from the animal kingdom. They may occur in a natural state or they may be produced artificially from inorganic or organic substances, which may be either non-poisonous or possess quite different properties. Many of the most important poisons are products of either plant or animal life, and are formed either within the tissues of the plant or animal, or from their food-supply by the transformation of substances which are either inert or possess an entirely different action.

The most important poisons belonging to the mineral kingdom or which are produced from minerals are: metallic mercury, chlorine, bromine, iodine, sulphur, and various combinations of these substances, different combinations of arsenic, antimony, lead, barium, iron, copper, silver, zinc, potassium, sodium, chromium, etc. Of the poisons containing carbon, which are artificially produced, the most important are: chloroform, chloral hydrate, ether, alcohol, iodoform, carbon bisulphide, hydrocyanic acid, potassium cyanide, oxalic acid, nitroglycerin, amyl nitrite, petroleum, carbolic acid, nitrobenzole, picric acid, and aniline. It may be observed in this connection that modern chemistry is constantly producing new substances, some of which are poisons.

Of the poisons produced by plants of the higher order, those of chief importance are: the *vegetable alkaloids*, such as morphine, quinine, colchicine, atropine, hyoscyamine, veratrine, strychnine, curarine, solanine, nicotine, digitaline, santonin, aconitine, cocaine, coniine, muscarine, and ergotine, all of which in relatively small doses may cause poisoning.

The lower forms of plant life, especially bacteria, produce an extraordinary variety of both poisonous and non-poisonous substances, out of the food material (albuminous bodies) in which they develop. Some of these substances are similar to the vegetable alkaloids, others to the ferments, and are therefore designated *toxic cadaveric alkaloids*, *toxic ptomaines*, *toxins*, *toxalbumins*, and *toxenzymes* (compare § 10). It may happen that the blood, flesh, or any organ of a healthy animal may acquire poisonous properties as a result of changes set up in it through the growth of bacteria. Such diseases due to bacterial poisons in the food are known as *botulismus*, *sausage*, *meat*, *fish*, and *cheese poisoning*. These conditions are to be explained, in part, by the growth of germs in the food-stuff and

the formation of toxic products out of the albuminous bodies; in part by the fact that germs were present in the tissues of the animal before death, the animal being slaughtered while diseased, and the use of its flesh as food causes either poisoning or the same disease as that affecting the animal. Under certain conditions foods which are not spoiled may already contain bacteria, and these may develop in the intestine of the individual eating the food and cause poisoning through the production of toxins, toxalbumins, or enzymes.

According to Lombroso, the disease *pellagra*, which is of common occurrence in Italy, Roumania, and Greece, is caused by the eating of decomposed corn. The disease *kakké* or *beri-beri*, which is endemic in Japan, is regarded by Miura and Yamagiva as due to the extended use of rice which has been spoiled in drying.

Among the animals which normally produce poisons within certain tissues of their bodies, the best known are: serpents, toads, salamanders, fish, mussels, oysters, scorpions, Spanish flies, and many stinging insects. Certain forms of sea-fish are poisonous at all times, others only at certain periods, and observations have been made particularly of such fish found in Japanese waters. According to Saotschenko, the poison of many poisonous fishes is secreted by certain skin-glands found at the roots of the dorsal and caudal fins, and may be found also in the eggs of such fish. According to Remy, Miura, and Takesaki, the poison is secreted in the sexual glands alone in the case of the poisonous fish belonging to the family *Gymnodontes* (tetrodons). According to Mosso, there is found in the blood-serum of eels a toxic substance (ichthyotoxin) which, when introduced into the small intestine of animals experimentally, causes symptoms of poisoning and may kill the animal. The observations made of cases of poisoning from the eating of mollusks occurring some years ago at Wilhelmshafen excited general interest; in these cases it was found that the eating of mussels (*Mytilus edulis*) caused severe illness, resulting in some cases in death.

According to M. Wolff, the liver of mussels contains the poison; its action, according to Schmidtmann, Virchow, Salkowski, and Brieger, is similar to that of curare. Brieger has also shown that from the poisonous mussels there can be obtained basic substances closely related to ptomains, the basic products of decomposition. To what extent the causes of the production of poisons in poisonous fishes and mollusks are to be ascribed to normal, and to what extent to pathological processes of life, cannot at the present time be always decided. From the fact that the mussels and oysters are poisonous only in certain places where the water is impure, and as the starfish found in the same localities are similarly affected, it is probable that the poisonous action of these mollusks may in part be due to their contamination with bacteria or to the occurrence of certain diseased conditions.

It is difficult to give an exact definition of poison and poisoning, since the action of the substances considered in this connection varies greatly according to the dose and attenuation, as well as the method of introduction into the tissues of the body. The most powerful poisons when introduced in minute doses may not only be harmless, but may exert a beneficial or curative effect. On the other hand, substances which are not usually classed with the poisons, such as the non-corrosive sodium salts, when introduced into the body in large quantities or in concentrated solutions, may produce effects which must be regarded as of the nature of poisoning. Further, poisons in certain dilutions (phenol) may serve as food-material. In the definition given above I have followed *Kobert*, and in the brief survey over the action of poisons contained in the succeeding paragraphs I have made much use of his "Textbook on Intoxications," published in 1893.



Snake-poison is formed exclusively in the poison-glands located above the angle of the mouth. It is a greenish or yellowish fluid, the virulency of which is not affected by desiccation or preservation in alcohol. The active principle is a toxalbumin.

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- See § 12 for literature of Ptomaines and Toxins.

§ 7. **Poisons** may be divided according to their action into three groups: first, those producing local tissue-changes; second, those acting injuriously upon the blood; third, those affecting chiefly the nervous system and the heart without producing recognizable anatomical lesions.

The poisons which cause marked local lesions injure primarily the tissues with which they first come into contact upon entering the body. If such poisons are diffused by means of the body-fluids, the most diverse organs and tissues may be injured; but their action is usually limited to that organ in which they are stored up or through which they are excreted, especially the liver, intestine, and kidneys.

The primary seat of injury is most often the mucosa of the upper portion of the intestinal tract and the respiratory passages, but in many cases the skin is first affected. Very frequently poisons, which are employed for disinfecting, are brought into contact with wounds for the purpose of killing bacteria or preventing their growth, and in this way may cause local changes or may be absorbed and damage the internal organs or the entire body.

The first great group of poisons belonging to this class are those which cause marked tissue-changes at the primary point of contact, which are similar to those of burns, and for this reason have been designated **caustics** or **corrosives**. If the action of a caustic reaches its most characteristic severity, the affected tissue will be wholly destroyed and converted into either a dry, hard eschar, or under certain conditions into a moist, soft one. If the action is of moderate intensity as the result of a less concentrated solution of the caustic agent, or of incomplete action of the chemical even when applied in strong solution or in substance, or because the tissue itself is more resistant as in the case of the skin, the changes produced are much less severe, and are characterized by redness, swelling, inflammation, and hæmorrhages. Very diverse changes

are often found in the same organ, such as local sloughing (necroses), hæmorrhages, inflammations, and small swellings due to local hyperæmia. If the changes have existed for some time, the local eschars are surrounded by a more or less marked inflammatory zone, which in the case of certain caustics may be of very limited extent.

The substances belonging to the class of caustic poisons are: first, the *corrosive acids*, sulphuric, nitric, hydrochloric, phosphoric, oxalic, arsenic, arsenious, osmic, acetic, lactic, trichloroacetic, carbolic, and salicylic acids; and further, the *corrosive combinations of the alkalis and alkaline earths*, potassium and sodium hydroxide (watery solutions of KOH and NaOH), caustic ammonia (solution of  $\text{NH}_3$  in water), ammonium carbonate, caustic lime, and barium sulphate. Belonging in this class are also certain *corrosive salts*, chiefly of the heavy metals, such as salts of antimony (tartar emetic and antimony trichloride), salts of mercury (corrosive sublimate and red precipitate), nitrate of silver, zinc chloride, zinc sulphate, copper sulphate and copper acetate, aluminum acetate, potassium chromate and bichromate, and chloride of iron.

The *poisons belonging to this class derived from animals* are: cantharidin, from the beetle *Lytta vesicatoria*; phrynin, the secretion from the cutaneous glands (parotid) of the toad; the secretions from the poison-glands of snakes and scorpions; the secretion of the sting-glands of bees, wasps, and hornets; the secretion of the salivary glands of stinging-gnats, flies, and gad-flies; and the secretion of the poison-glands of the maxillary palpæ of spiders (tarantula)—all of which cause local necrosis or inflammation. Many of the *higher plants* produce in their blossoms, seeds, stems, or roots substances which, when brought into contact with the tissues, cause local irritation and inflammation, as, for example, daphne, different forms of *Ranunculus*, varieties of anemone, marsh-marigold, different varieties of *Calla*, dragon-root, *Croton tiglii* (from the seeds of which croton-oil is obtained), buckthorn (*Rhamnus cathartica*), black elder (*Rhamnus frangula*).

The nature of the local changes which these substances and many others not mentioned here produce is naturally very varied, and is dependent partly upon the activity of the poison, and partly upon the location and manner of application. The mineral acids, solutions of caustic potash and mercuric chloride, when concentrated, cause marked tissue-eschars, associated with hæmorrhagic inflammations, especially when taken into the stomach. Through the action of acids there is a marked withdrawal of the alkaline constituents of the body fluids, leading to disturbances of respiration and circulation. The venom of snakes, which belongs to the toxalbumins, causes usually severe local inflammations and hæmorrhages, which often extend far beyond the region of the bite; and sometimes may cause also a widespread gangrene. There are also snake-venoms which produce only insignificant local changes, the general symptoms of poisoning being much more prominent. The *volatile or gaseous* poisons, which in the form of gas or vapor cause local irritation of the tissues, affect chiefly the mucous membranes of the eye and respiratory tract (*irrespirable gases*). To this class belong especially the fumes of ammonia, chlorine, sulphurous acid, nitric oxide, nitric dioxide, nitric trioxide, osmic acid, and mustard oil. The intensity of action of these poisons is very varied, often causing only a transitory hyperæmia, but being able also to give rise to tissue necrosis and severe inflammation. The irritation of the respiratory tract gives rise to coughing and a spasmodic narrowing of the glottis which may interfere with breathing.

To the local irritation and inflammation caused by these poisons at the primary seat of contact may be added further *effects upon internal organs*. After the absorption of these poisons into the fluids of the body, those organs suffer most in which the poison is stored up or elaborated, though organs of the most varied structure may be affected, as well as those not concerned in the excretion of the poison. In the case of certain poisons, the changes at the point of entrance are very slight and often not recognizable, the important anatomical lesions occurring first in other tissues, to which the poison has been carried by the blood. Finally, a given poison may act also as a *nerve and heart poison*, so that clinically the effects of this action are much more prominent than the local lesion. In poisoning with corrosive sublimate, cell necrosis takes place in the secreting part of the kidneys, and there is also severe inflammation of the colon. The salts of chromic acid, cantharidin, and many acids cause more or less marked degeneration and inflammation in the secreting portion of the kidney and in the urinary passages.

Phosphorus, arsenic, antimony, and pulegon, which have but slight corrosive action, produce tissue-degenerations, particularly fatty degeneration, and also hæmorrhages, in the liver, heart, muscles, bone-marrow, and capillaries of different organs, these changes being particularly marked in cases of phosphorus poisoning.

If an individual is exposed for months or years to the fumes of yellow phosphorus, there may take place an inflammation of the jaw bones leading to necrosis, but only when the occurrence of inflammatory changes is favored by other causes, such as putrid decomposition in the mouth or the presence of decaying teeth.

The long-continued use of silver nitrate may be followed by a deposit of black granules of silver in the most diverse tissues, the skin, kidneys, intestinal villi, and the choroid plexus.

The venom of snakes possesses, in addition to its local effects, a paralyzing action upon the nervous system and heart, and may cause death through paralysis of the respiratory centre.

Soluble salts of lead when ingested may cause irritation and inflammation of the intestine, with such symptoms as vomiting, diarrhœa, constipation, cramps in the stomach, associated with such nervous phenomena as anæsthesia, motor paralysis, convulsions, vertigo, and loss of consciousness. When ingested continuously for a long time, lead gives rise to general disturbances of nutrition, intestinal colic, pains in the limbs, anæsthesias, motor paralyses, cerebral disturbances, and kidney disease. These disturbances are without doubt dependent upon the distribution and deposit of lead throughout the body, leading to anatomical lesions of varied nature.

The active principles of *ergot* (*Secale cornutum*), sphacelinic acid and cornutin, when taken in large doses, as when eaten in bread, cause itching, pain, and cramps in the limbs, followed by numbness and feeling of cold in the toes and finger-tips, and finally there may occur a more or less extensive gangrene of these parts (*ergotism*, "*Kribbelkrankheit*") ; at the same time ulceration of the intestine may occur. In cases of chronic poisoning, degenerations of the spinal cord take place (Tuczek). The feeding of chickens with ergot causes gangrene of the comb through the production of stasis and hyaline thrombosis in the blood-vessels. In animals fed for a long time with ergot degenerative changes are found in the central and peripheral nervous system, in the blood-corpuscles, and in the endothelium of the blood-vessels (Grigorjeff).

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§ 8. The *poisons which affect the blood chiefly*, and are therefore termed *blood-poisons*, are partly gases and partly fixed substances. The latter

are absorbed chiefly from the intestine, but they may also enter the body through wounds, or they may be injected directly into the blood-vessels. Some of the blood-poisons may also produce local lesions in the tissue at point of entrance; further, there may be joined to the action on the blood a direct effect upon the nervous system, which under certain conditions may cause death before the action upon the blood is recognizable. Finally, it should be emphasized that the blood-changes produced by the poison may cause numerous secondary changes in different organs, for instance, in the kidneys, liver, intestine, and brain.

The most important blood-poison is *carbon monoxide* gas, in that it very frequently leads to more or less serious or fatal poisoning, through its action on the blood. Such poisoning most often results from the carbon monoxide in coal- or illuminating-gas, but may occur under other conditions, as in the case of the vapors produced by gun-powder or gun-cotton.

The effects of the inhalation of carbon monoxide result from the combination of the gas with the hæmoglobin of the blood and the formation of carbon-monoxide-hæmoglobin. The amount of oxygen combined with the hæmoglobin is thereby decreased, and the taking up of oxygen is reduced, even when the respired air contains only 0.05 per cent or even 0.02 per cent of CO (Gruber). The red blood-cells themselves present no changes. A sudden supply of carbon monoxide to the nervous system may cause direct injury to the nerves, giving rise to convulsions and later to paralysis (Geppert). In cases of long-continued poisoning the displacement of the oxygen from the greater portion of the red cells leads to tissue-asphyxia. If the affected individual does not die, there may result, in addition to the poisoning, severe disturbances of nutrition, occurring especially in the nervous system. The poisoning itself is characterized by headache, tinnitus aurium, vertigo, malaise, vomiting, fainting, convulsions, paralysis, and coma. The blood, as a result of the presence of carbon monoxide, becomes a bright violet or cherry-red color, so that the hyperæmic skin and internal organs also appear bright red.

A second not infrequent form of poisoning is that caused by *hydrocyanic acid* (CNH) and *potassium cyanide* (CNK), the latter being much used in certain technical arts. In general, hydrocyanic acid is found in unstable combination in the leaves, bark, and seeds of many plants (bitter almonds, cherry- and peach-stones, apple-seeds, leaves of the laurel, bark of *Prunus padus*, tubers of many of the Euphorbiaceæ, flaxseed, etc.).

Hydrocyanic acid possesses a double action. In relatively small doses it exerts a paralyzing action upon the central nervous system, death following in a very short time, even after a few seconds, from the paralysis of the centres of respiration and circulation. In addition, there is an effect upon the blood and tissues, depriving them of their power to combine and use the oxygen brought to them (Geppert), so that the organs suffocate in the presence of oxygen. According to Kober, a cyan-methæmoglobin is formed which is of a bright-red color, and gives to the hypostatic spots of the cadaver a bright red appearance.

A third substance belonging to this group of poisons is *hydrogen sulphide* ( $H_2S$ ), which may be present in the gas of sewers and dung-pits. When inhaled in large amounts, it may cause sudden death from paralysis of the nervous system. When hydrogen sulphide is for some time

brought into contact with blood containing oxygen (as is usually the case in decomposing cadavers), a sulphur-methæmoglobin is formed, which gives to the blood a greenish color.

Carbon monoxide, hydrocyanic acid, hydrogen sulphide, aside from their direct action on the nervous system, produce deleterious effects, chiefly, according to the statements made, in decreasing the functional powers of the red blood-cells, by combining with their hæmoglobin.

Another large group of poisons affect the blood chiefly, by the destruction of the red blood-cells, and the formation of methæmoglobin, a combination of oxygen with the hæmoglobin in the same proportion as in oxyhæmoglobin, but in which the oxygen is much more firmly held than in the case of the latter. Such an action is produced by various oxidizing substances (ozone, iodine, sodium hypochloride, chlorates, nitrites, and nitrates); by reducing agents (nascent hydrogen, palladium hydride, pyrogallol, pyrocatechin, hydrochinon, and alloxanthin); also by substances which have neither a reducing nor oxidizing action (salts of aniline and toluidin, acetanilid). In the change from hæmoglobin to methæmoglobin, oxyhæmoglobin is present as an intermediate stage.

The formation of methæmoglobin can occur either in the red blood-cells or in the hæmoglobin which has escaped into the blood-plasma; but the destruction of the blood-cells and the escape of hæmoglobin into the plasma are not always followed by the formation of methæmoglobin. In the case of a marked destruction of red cells, as in poisoning from phallin, helvellic acid, arseniuretted hydrogen, only a portion of the hæmoglobin is changed into methæmoglobin. Hæmoglobin and oxyhæmoglobin have a red color, methæmoglobin a sepia-brown.

Dissolution of the red blood-cells and the formation of methæmoglobin occur in the case of a part of those poisons causing local tissue-changes, as in poisoning with acids, metallic salts, phosphorus, and arsenic, but the property of attacking the red cells and changing the coloring-matter belongs also to a large class of other substances.

*Phallin*, a toxalbumin present in certain mushrooms (*Amanita s. Agaricus phalloides*), *helvellic acid*, contained in the fresh morel, *Helvella esculenta* (the poison is lost through drying), *arseniuretted hydrogen* ( $\text{AsH}_3$ ), *the ethereal extract of male fern*, cause destruction of the red cells with a resulting increased formation of bile-pigment and a deposit of derivatives of the blood-pigment in the liver, kidneys, and bone-marrow. *Potassium chlorate* ( $\text{KClO}_3$ ), *pyrogallol* ( $\text{C}_6\text{H}_3[\text{OH}]_3$ ), *hydrazin* ( $\text{H}_2\text{N}-\text{NH}_2$ ), *toluylendiamin* ( $\text{C}_6\text{H}_4[\text{NH}_2]_2$ ), *nitrobenzol* ( $\text{C}_6\text{H}_5\text{NO}_2$ ), *nitroglycerin* ( $\text{C}_3\text{H}_5[\text{NO}_2]_3$ ), *amyl nitrite* ( $\text{C}_5\text{H}_{11}\text{NO}_2$ ), *picric acid* ( $\text{C}_6\text{H}_3[\text{NO}_2]_3\text{OH}$ ), *aniline* ( $\text{C}_6\text{H}_5\text{NH}_2$ ), *carbon disulphide* ( $\text{CS}_2$ ), are distinctive in their action, in that they cause formation of methæmoglobin, sometimes with destruction of the red cells, at other times without.

Large doses of potassium chlorate may cause death in a few hours, through the destruction of the red blood-cells and through the action of the potassium, with the occurrence of vomiting, diarrhœa, dyspnœa, cyanosis, and cardiac insufficiency. The blood becomes chocolate-brown in color. In more protracted cases of poisoning by smaller doses the products of blood destruction are found in the spleen, liver, bone-marrow, and kidneys. The urine in these cases may vary in color from a reddish-brown to black (methæmoglobin). Delirium, numbness, coma, and convulsions occur, showing the marked involvement of the central nervous system. Pyrogallol produces similar symptoms. Hydrazin and phenylhydrazin produce multiple thrombosis, in addition to the de-

struction of red cells and formation of methæmoglobin. In poisoning with toluylendiamin the essential feature is a destruction of the red cells, with a deposit of iron-containing pigment in spleen, liver, and bone-marrow. In cats hæmoglobin may be excreted by way of the urine (Biondi). In picric-acid poisoning there occurs, in addition to the destruction of blood-cells and formation of methæmoglobin, a severe irritation of the central nervous system, characterized by violent convulsions. Aniline and carbon disulphide not only injure the blood, but also give rise to irritation and paralysis of the nervous system.

According to Kobert, *ricin* derived from the seeds of the castor-bean, and *abrin* from the seeds of *abrus precatorius*, should be classed with the blood-poisons, in that in the test-tube they cause an agglutination of the red cells and the formation of a flocculent precipitate. In animals poisoned experimentally, local irritations, tissue-degenerations and inflammations, similar to those caused by certain bacterial toxins, are produced, as well as disturbances in the centres of the medulla oblongata, leading to cessation of respiration with progressive falling of blood-pressure. Tissue-degenerations, inflammation, and hæmorrhage are found, after longer action, at the point of application and in the intestine, where the poison is excreted. Degenerative changes are also found in lymphocytes, liver and kidney cells, and heart muscle.

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§ 9. The last group of poisons, generally classed together as **nerve and heart poisons**, is characterized chiefly by the fact that, in spite of the severity of the symptoms, as shown in the form of irritations and paralyses, anatomical changes either cannot be recognized at all or are confined to structural changes in the protoplasm of individual nerve-cells, which are of similar character in the case of different poisons. This is especially the case when the poison is quickly fatal, while if the poisoning runs a protracted course, or in the case of chronic poisoning from small doses, extending over months and years, there are very often found marked anatomical changes—a fact which may be taken as evidence that these poisons do not produce solely functional disturbances of the nervous system, but cause injury to the cell-protoplasm which may be manifested in the form of degenerations.

Of the very great number of *poisons which act especially upon the nervous system* and may cause death through its paralysis, the most important are: chloral hydrate, opium and its alkaloid morphine, cocaine, atropine, hyoscyamine, daturine (stramonium-atropine), nicotine, coniine, cicutoxin, santonin, camphor, quinine, veratrine, colchicine, aconitine, strychnine, cytisin, curarine, and samandarine (salamander-poison).

Of the *heart-poisons*, digitalin, helleborin, muscarine, and phrynin (poison of toads) are of special importance.

*Chloroform* ( $\text{CHCl}_3$ ), when applied directly to the mucous membranes, causes local irritation and may produce transitory inflammation. When conveyed to the blood through inhalation or by absorption from the intestinal tract, it gives rise, after a short period of stimulation, to a condition of diminished irritability of the cerebral gray and white matter. According to Binz, the protoplasm of the ganglion-cells suffers a slight coagulation. Death may be caused by paralysis of the central nervous system, as well as by a premature heart-failure; the latter, however, occurring only when the heart is abnormally weak or degenerated, or possibly when the irritation produced by the chloroform upon the mucous membrane of the nose causes a strong reflex stimulation of the inhibitory nerves of the heart. The long-continued use of chloroform may cause degenerative changes in different organs, as the heart, kidneys, liver, muscles, and blood.

*Ether* (diethyl ether  $\text{C}_2\text{H}_5\text{OC}_2\text{H}_5$ ) acts similarly to chloroform, but is less poisonous, and acts less detrimentally upon the heart.

*Nitrous oxide* ( $\text{N}_2\text{O}$ ) acts chiefly upon the cerebrum, lowers the sensibility of pain, and paralyzes consciousness; later, the action may extend to the spinal cord, the medulla oblongata, and the heart.

*Alcohol* ( $\text{C}_2\text{H}_5\text{OH}$ ), after a transitory stimulation, has a depressing and paralyzing action upon the brain, at the same time causing a dilatation of the arteries of the skin, so that in intoxicated individuals severe chilling through the skin may easily occur. Death may take place suddenly, with symptoms similar to those of apoplexy; more frequently there is a gradual loss of consciousness and of sensory perception, the respiration becomes slower, the pulse small, the face cyanotic; complete coma and general paralysis forming the closing symptoms. The immoderate use of alcohol for months

or years may, on the one hand, give rise to pathological deposits of fat in those regions where fat is normally found; on the other hand, to fatty degeneration of glandular organs, particularly of the kidneys and liver; also degenerative atrophies of liver and kidneys associated with increase of connective-tissue; further, sclerosis and atheroma of the arteries, degeneration of the brain, etc., are ascribed to the action of alcohol. At the present time it is impossible to say in what manner, how often, and to what extent these changes are dependent upon the use of alcohol. It is certain, however, that drunkards suffer frequently from disturbances of digestion and circulation, catarrhal inflammations of pharynx, larynx, and bronchi, and disturbances of cerebral function; and that the disease of the brain known as delirium tremens, which is characterized by general muscular tremors, obstinate insomnia, anxiety, and hallucinations, is especially to be ascribed to alcoholism.

*Chloral hydrate* ( $\text{CCl}_3\text{CHO} \cdot \text{H}_2\text{O}$ ) causes local irritation of mucous membranes, and through the blood produces paralysis of the brain, spinal cord, and heart, and thus induces sleep. In fatal doses, death follows deep coma as a result of œdema of the lungs due to the general relaxation of the tissues.

*Opium* and *Morphine* ( $\text{C}_{17}\text{H}_{19}\text{NO}_5$ ) depress the cerebral functions, thereby inducing sleep; in individual cases there may be a preceding period of stimulation. Large doses lead to unconsciousness, paralysis of muscles, slowing and weakening of the heart's action, contraction of the pupils, slowing of intestinal peristalsis, diminution in the exchange of gases in the blood dependent upon diminished excitability of the respiratory centre. There is no characteristic autopsy finding; the blood is usually dark and fluid. The chronic use of opium may give rise to digestive disturbances, emaciation, vertigo, sleeplessness, neuralgias, imbecility, impotence, weakness of the bladder, hallucination, tremors of the hands and feet, fever, etc., yet these symptoms may vary much in different individuals. In chronic morphinism the organism becomes accustomed to increasingly larger doses; withdrawal of the drug causes severe nervous disturbances, and under certain conditions dangerous collapse.

*Cocaine* ( $\text{C}_{17}\text{H}_{21}\text{NO}_4$ ) produces peripherally a dulling of the excitability of the sensory nerve-endings; centrally, first a stimulation and later a paralysis. The chronic use of cocaine gives rise to symptoms similar to those of chronic morphinism.

*Atropine* and *hyoscyamine* ( $\text{C}_{17}\text{H}_{23}\text{NO}_3$ ), the alkaloids which are found in the Solanaceæ (deadly nightshade, thornapple, and henbane), cause paralysis of the peripheral nerve-organs and a central stimulation, followed later by paralysis. Solutions of atropine introduced into the eye produce dilatation of the pupil and paralysis of accommodation for near vision, through its paralyzing action on the endings of the motor oculi in the iris. Atropine may further cause suppression of the secretion of certain glands (as the submaxillary); it also inhibits intestinal peristalsis. As a result of the action of this poison upon the brain, a condition of excitement, gayety, inclination to laugh, leading even to insanity and frenzy, may be produced, followed by paralysis. The autopsy findings are negative.

*Nicotine* ( $\text{C}_{10}\text{H}_{11}\text{N}_2$ ), a volatile alkaloid found in the tobacco plant, acts upon both peripheral and central nervous systems, causing nausea, salivation, vomiting, diarrhoea, vertigo, muscle weakness, headache, convulsions, delirium, and paralysis. Chronic nicotine poisoning may give rise to nervous affections and disturbances of the heart's action. According to *Vas*, there is in both chronic nicotine and alcohol poisoning a degeneration of the ganglion-cells characterized by a homogeneous appearance of the chromatin.

*Coniine* ( $\text{C}_8\text{H}_{17}\text{N}$ ), the alkaloid present in hemlock, causes paralysis of the peripheral motor nerve-endings, first stimulating and then paralyzing the central nervous system. *Cicutoxin*, a poisonous resin obtained from the water-hemlock (*Cicuta virosa*) produces nausea, vomiting, attacks of colic, cardiac palpitation, convulsions, and unconsciousness.

*Santonin* ( $\text{C}_{11}\text{H}_{11}\text{O}_5$ ) causes convulsions by its action on the brain and spinal cord, with benumbing of the sensorium, vertigo, vomiting, salivation, and yellow vision or xanthopsia, in which white is seen as yellow and blue as green.

*Quinine* ( $\text{C}_{20}\text{H}_{21}\text{N}_5\text{O}_8$ ), the most important of the numerous alkaloids contained in the bark of cinchona and other closely related plants, has a paralyzing action upon living protoplasm, and in relatively small doses lowers the functional capacity of the brain. Large doses produce death through paralysis of the centre of respiration and of the heart.

*Aconitine*, *colchicine*, and *veratrine* produce local irritations and, later, benumbing of the peripheral endings of the sensory nerves. On the central nervous system they have first a stimulating action, later a paralyzing.

*Strychnine* ( $\text{C}_{21}\text{H}_{23}\text{N}_5\text{O}_8$ ), obtained chiefly from the plant *nux vomica*, causes an increased reflex excitability of the nerve centres, so that the slightest external stimulus may produce tetanic convulsions. Death may occur in from ten to thirty minutes

after the first convulsion, and is the result of central paralysis, namely, of the vasomotor centre.

*Curarine* ( $C_{12}H_{11}N$ ), the active principle of the arrow-poison curare, is probably derived from the cortical portion of the roots of different plants of the strychnia family. When used in small doses it paralyzes the endings of the motor nerves of the muscles. Larger doses cause paralysis of the central nervous system and of the vasomotor nerves, after a temporary stimulation.

*Digitalin* and *digitalein*, two glucosides obtained from the foxglove, act as local irritants; after absorption they stimulate the heart, vagus-centre, and the musculature of the blood-vessels, so that with a slowing of the heart-beats there is an increase of blood-pressure. Large doses cause headache, delirium, tinnitus aurium, irregular increase in the frequency of the heart's action, convulsions, and coma.

*Helleborin*, a glucoside obtained from hellebore, acts similarly to the preparations of digitalis.

*Muscarine* ( $C_8H_{11}NO_2$ ), the poison of the fly-agaric, acts as a stimulant to those nerve-endings which are paralyzed by atropine. The intense excitation of the inhibitory centres of the heart causes stoppage of the unparalyzed heart, and death is thereby produced. The general symptoms of muscarine poisoning are salivation, vertigo, anxiety, nausea, vomiting, diarrhoea, convulsions, and finally unconsciousness. Small doses produce a condition of excitation similar to that of drunkenness.

The above summary of poisons, which is of necessity confined to a limited number, I have based upon the generally accepted classification, which *Kobert* has also retained in his text-book on intoxications. A more exact knowledge of the action of poisons than we now possess will surely in the future be made a basis for a different classification. *Loew* (see literature to § 6) has recently attempted to make a classification of poisons according to their action upon the living organism, that is, upon the living protoplasm. He distinguishes two great groups, namely, *general poisons*, which in moderate concentration are fatal to all living organisms; and *special poisons*, which have no injurious effect upon certain classes of organisms. The general poisons are characterized chiefly by their power to change the chemical character of the active protein-bodies, out of which living protoplasm is formed. They may be classed as follows: (1) *Oxidizing poisons* (ozone, chromic acid, manganic acid, hypermanganic acid, hypochlorites, hydrogen peroxide, chlorine, bromine, iodine, phosphorus, arsenious acid); (2) *poisons having a catalytic action* (ethyl ether, chloroform, chloral, many hydrocarbons, etc.), which transfer to the protoplasm the unstable condition of their molecules, and so lead to chemical changes in the unstable albumin; (3) *poisons acting by the production of salts* (acids, soluble mineral bases, and corrosive alkalies, alkaline earths, salts of the heavy metals), which form with the protein-bodies chemical combinations of the nature of salts; (4) *substitution poisons* (hydroxylamin, diamide, phenylhydrazin, ammonia, phenol, hydrocyanic acid, etc.), which even when greatly diluted interfere with the aldehyde or amido-groups. The *special poisons* are classified as follows: (1) *Toxic proteids*, i.e., (a) *toxalbumins* (produced by bacteria and poisonous to animals); (b) *alerins* and *immunotoxins* (produced in animals physiologically or pathologically, and poisonous for bacteria); (c) *vegetable enzymes* (abrin, ricin, produced from phanerogams and the higher fungi, and poisonous to animals); (d) *animal enzymes* (produced by certain animals, snakes, fishes, and spiders, and poisonous to other animals); (2) *organic bases* (strychnine, atropine, curare, etc.), having an unexplained action; (3) *poisons acting indirectly*, which interfere with the processes of respiration (carbon monoxide, sulphites), or which act as poisons through decomposition (nitrites, iodine combinations), or which cause structural alterations through changes in the tumidity ("Quellungszustand") of certain organized tissues (neutral alkaline salts, alkaline earths, oxalates).

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#### 4. Origin of Disease through Infection or Parasitism. *Miasms and Contagion. Vegetable and Animal Parasites.*

§ 10. As seen in the last sections (§ 6 to § 9), there occur in the intoxications certain morbid vital phenomena, which are caused by definite chemical substances, the mode and severity of whose action, in so far as the idiosyncrasy of the poisoned individual and the especial manner of application of the poison are not considered, depend not only upon the character of the poison but also upon the size of the dose employed.

In those diseases which arise from infection and which are called *infectious diseases*, we have, on the contrary, to deal with *morbid vital phenomena*, which, if we disregard the susceptibility of the infected individual and the especial mode of entrance of the infecting material into the body, are dependent *solely upon the character of the infecting agent*, while the dose is of little or no significance.

The essential difference between intoxication and infection lies in the fact that in the first case there is no increase of the poison within the body, while *in infection the harmful agent increases after its entrance into the organism*, so that the smallest possible amount of the infective material may give rise to the most severe and fatal disease. The size of the dose of the infecting agent has an influence upon the succeeding illness only in so far as the probability of infection (that is, reproduction of the injurious agent within the body) is increased with the amount of the

same taken into the body, and that consequently the reproduction of the infective agent may in shorter time reach such proportions as to give rise to pathological tissue-changes and symptoms of disease.

The injurious agents causing the infectious diseases enter the human organism from the external world and give rise to an *illness which may run a pathognomonic course*; and from the peculiarities of this course it may be possible to conclude that the disease is due to a specific organism possessing a characteristic action. In the case of pregnant women the infective agent may be transmitted from the organism of the mother to the foetus in utero.

If an infectious disease attacks a great number of individuals in a given locality, it becomes a **pestilence** or an **epidemic**.

Experience based upon clinical observation teaches us that in some cases the injurious agent which causes a certain infectious disease is active only in certain regions and infects (that is, makes ill) individuals who live in this region. In other cases it is seen that contact with a diseased individual, or proximity to such, or the use of some object touched by the affected person or contaminated in other ways—for example, through dejecta or through sputum—may produce the disease. Finally, it may also be noted that infective material develops only at certain times in a given locality, and only when an infected individual visits that particular region and through his presence leads to the production there of the infective material.

From these varying conditions occasion has been taken to divide the agents capable of causing infection into different groups and to designate these by particular names. If the infective agent is connected with a certain locality it is termed a **miasm**, the conception underlying this being that the affected region produces the injurious material. If only a particular region produces the infective agent, the term *local miasm* is used; but if universally present, a *ubiquitous miasm*. To the miasmatic diseases belong especially malaria, croupous pneumonia, articular rheumatism, many wound-infections, septic osteomyelitis, and ulcerative endocarditis.

The conveyal of an infection from man to man directly or indirectly and its spread through houses, villages, cities, and countries is termed a **contagium**; and it is thereby understood that the production of the infective agent takes place only in the human body, or in some lower animal, its development and increase outside of these being impossible. To such contagious diseases belong smallpox, measles, scarlatina, diphtheria, typhus fever, recurrent fever, anthrax, hydrophobia, gonorrhœa, whooping-cough, influenza, many catarrhs of mucous membranes, tuberculosis, syphilis, glanders, and leprosy.

If an infective agent develops in a certain locality only when an infected person visits the region and thereby gives rise to an epidemic, the term **miasmatic contagious disease** is used, with the assumption that the infective agent had spread from the body of the first patient into the outer world, and had somewhere multiplied, and either alone or through the aid of special local influences had been able to produce in the inhabitants of the region an epidemic spread of the disease. To such miasmatic-contagious diseases belong cholera, typhoid fever, dysentery, yellow fever, and bubonic plague.

The nature of miasmatic and contagious diseases was unknown to the older practitioners. The occurrence of an infectious disease as a plague or epidemic was explained by causes sought in peculiar cosmic or telluric

conditions, and these were designated *constitutio epidemica* or *constitutio pestilens*. Only in the last decade has our knowledge of the causes and nature of the infectious diseases made true advances, and it has been demonstrated that the infectious diseases are **parasitic diseases**, *the origin of which is to be attributed to the increase of small living organisms within the human body*. It is true that the parasitic cause has been positively demonstrated in only a part of the infectious diseases, but it is highly probable that all are caused by parasites. To the hypothesis that the causes of infectious diseases were to be sought in living organisms, capable of reproduction, in a *contagium animatum*, the earlier investigators were led chiefly by the fact that the infective agent causing a certain disease could, when once present, constantly renew itself and indefinitely increase, so that from a single case of the disease an endless number might be infected; and further that extremely small and imponderable quantities of the infective material were sufficient for the infection of an individual, so that the intense effects of an infection upon the human organism could be explained only by the assumption of an increase of the infective agent within the body.

The attempt has also been made many times to explain the phenomena of infection through the action of injurious gases or soluble ferments. Such hypotheses are wholly unsatisfactory, inasmuch as they leave unexplained the chief phenomena of the spread and course of epidemics, or the explanations adduced are open to well-founded objections.

The parasites which cause infectious diseases belong to the lowest forms of plant and animal life. Among the plants the **schizomycetes** or **bacteria**, among the animals the minute organisms belonging to the **protozoa**, play the most important rôle in the production of disease. Of the more highly organized plants the **saccharomycetes** and **hyphomycetes** may act as infective agents, but their pathological significance is much less than that of the bacteria. Among the animals, numerous **worms** (Nematodes, Trematodes, Cestodes) and **arthropoda** (Arachnida and Insects) occur as human **parasites**, but their action is much more limited, and the pathological conditions produced by them are not ordinarily classed as infectious diseases in the narrow sense of the term.

For the production of a true infection, it is necessary that a given parasite must increase in the human body and produce a number of generations, which spread more or less widely through the tissues. If the itch-mite, which produces many generations in the epidermis, be excluded, the parasitic Schizomycetes, Saccharomycetes, and Protozoa alone are to be regarded as fulfilling the above condition; the higher animal parasites passing only a part of their life within the human body—that is, within the same host. Those parasites which multiply within the invaded organs, through the production of eggs or of matured embryos or of larvæ, do not become sexually reproductive in the same host.

**Parasitic infection**, that is, the *entrance of parasites into the human body, and their increase*, can occur in almost every part of the body. The most common avenues of infection are the *mucous membranes which admit of access from without*, especially the respiratory and intestinal tracts, which in particular favor the entrance of parasites. In many cases the parasites are contained in the food and drink, especially in water. Since the pathogenic organisms are for the greater part very small, and when suspended in the atmosphere may be carried about everywhere by means of the air-currents, they are often present in the respired air and so

reach the *air-passages* or *alveoli of the lungs*, where they may become attached to the walls and frequently obtain entrance into the tissues.

Further, *wounds* form a favorable place for the entrance of small parasites, and may be the starting-point of an infection through the entrance of the latter, either from the air or through contact with contaminated fluids or objects. Finally, parasites may establish themselves in the *uninjured skin*, and, increasing, give rise to an infectious disease.

The view that certain diseases, particularly the plague, were of parasitic origin, is very old, and found expression in the works of *Kircher* (1602-1680), *Lancisi* (1654-1720), *Linné* (1707-1778), and others. It has been left to very recent times, however, to place the theory of the parasitic origin of disease upon a secure foundation. Though several decades ago *Henle*, *Liebermeister*, and others asserted that the peculiarities of infectious diseases could be explained only by the assumption of a *contagium animatum*, the establishment of this doctrine is due to the results of the investigations of the last thirty years.

The influence which *climate* exerts upon man is, if the influence of temperature be not considered, essentially dependent upon the conditions of the soil of a given region with respect to the development of micro-organisms which are capable of causing disease. A rough windy climate may therefore be healthy, while one that is mild and subject to slight variations of temperature may be unhealthy. In the case of inhabited regions, the question naturally arises as to the prevalence of epidemics among the inhabitants. Temporary changes in the injurious influences of a certain climate are dependent partly upon the fact that the pathogenic organisms do not at all times increase in the same ratio, and partly that the micro-organisms present in the earth do not always get into the drinking-water or into the atmosphere, or at least obtain entrance into the human organism only at times.

According to *Pettenkofer*, the spread of miasmatic-contagious diseases, as, for instance, cholera, cannot be explained by the fact that bacteria from the dejecta of a cholera patient are able to survive outside of the body for a given length of time, and under favorable circumstances to increase, obtain entrance into the mouth by means of drinking-water, food, or unclean hands, reach the intestines, and again produce an infection. On the other hand, he believes that the disease-germs on reaching the soil are able to form their characteristic poisons only when certain temporary local conditions are present in the affected region, so that the disease germs combining with an unknown something, that is, under the influence of the soil, must acquire a higher virulence in order to form the characteristic poison of the disease. The latest researches concerning the etiology and spread of typhoid fever, cholera, and the plague do not support this theory; on the contrary, they show that the bacteria of cholera, typhoid fever, and the plague are sufficient in and of themselves in given cases to produce an infection. It follows from what has already been said that cholera germs, when introduced into the intestinal canal of man or of certain experimental animals, are able to cause cholera.

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- See also § 12.

§ 11. The disease-producing bacteria are extremely small, unicellular organisms, which appear in the form of little spheres (cocci), and fine, straight, or curved rods (bacilli and spirilla), frequently uniting in peculiar combinations. Some multiply in the external world, and only occasionally enter the human body; others, on the contrary, are so constituted that they cannot reproduce in the outer world and are able to multiply only when in the human or animal body. The *pathogenic bacteria* are therefore divided into two classes, *ectogenic* and *endogenic*; the first is identified with the *miasmatic diseases*, the latter with the *contagious*. There is, however, no sharp division-line between these two classes, inasmuch as certain bacteria which ordinarily multiply only in the human or animal organism, may, under certain conditions, develop in the outside world; so that in a certain sense a contagium becomes a miasm.

On the other hand, it is not necessary for the spreading of a disease caused by ectogenic organisms that the Schizomycetes develop outside of the human body; more frequently a direct infection from individual to individual takes place. For example, the bacilli of anthrax can multiply as well in the outer world as in the animal body, and the disease may be spread by direct transmission from man to man or from an animal to man, as well as by the entrance of the bacilli into the human or animal body through some infected culture-medium. The cocci which produce suppuration, or those causing inflammation of the lungs, can likewise infect a healthy individual directly from the outer world where they have multiplied, or from another diseased individual.

It follows therefore that *no sharp line can be drawn between miasms and contagions or between ectogenic and endogenic bacteria*. The distinction



is of value only in that in many infectious diseases one of the two forms of spreading predominates, and there are also infections in which, so far as our knowledge goes, there is but one mode of dissemination. For example, small-pox and measles, the infective agents of which have not yet been discovered, spread only by direct and indirect contagion; and it is also assumed that the poison of syphilis is not able to increase outside of the human body.

Pathogenic bacteria may be found outside of the human body, in solids, liquids, and in the atmosphere. Those forms which are able to multiply outside of the body (bacteria of cholera, typhoid, anthrax, suppurations, actinomycosis) are found especially in water fouled by organic substances, or in damp earth rich in organic material or in dead animal or vegetable tissue containing moisture. They are besides often present in dry earth and dried tissue, and can pass from these, as well as from fluids, into the air, their distribution being favored by dust, strong currents of air, and excessive sprinkling. In the drying of substances containing bacteria, a portion of the bacteria are killed, since they are not able to survive complete desiccation. Many of the pathogenic bacteria produce *resistant forms (spores)* which are able to bear long-continued and complete drying, and therefore to retain their vitality in the air. If these come into contact with firm bodies or fluids and remain attached to them, they may survive for a long period, and under favorable conditions—that is, if they find proper nourishment and sufficient moisture, and if the temperature reaches the height necessary for their development—they may again multiply.

Bacteria, which are not able to multiply outside of the human or animal body, or at least do so only under very special and rare conditions, are able to preserve themselves outside of the body for a length of time, only when they produce forms which survive desiccation, or are not killed by the chemical influences of their environment in the fluids, damp earth, and tissues in which they are found. For a limited time they may cling to the most varied substances and retain their vitality, so that for a certain length of time contaminated objects are capable of causing infection. Bacteria which are able to survive drying may be found in the dust of the streets, of the floors and walls of houses, as well as in the air itself, particularly so when the bacteria are thrown off in great abundance from the diseased individual in whom they have multiplied. This is especially true of the bacillus of tuberculosis, in that in pulmonary tuberculosis the sputum, in intestinal tuberculosis the feces, and in case of tuberculosis of the urogenital tract the urine, may contain great numbers of the bacilli.

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§ 12. The **avenues of entrance for bacteria** are, in general, the mucous membranes of the intestinal canal, respiratory tract, and the middle ear, the conjunctiva, the alveoli of the lungs, and open wounds. Through recent wounds, both pathogenic and non-pathogenic bacteria are rapidly taken up into the lymph and blood; while through wounds showing healthy, granulating, uninjured surfaces, the entrance of many bacteria into the tissues is hindered. Pathogenic bacteria not infrequently enter through the uninjured skin, either by way of the hair-follicles or through the sebaceous or sweat glands. Under especial conditions (coitus, surgical operations, dribbling of urine) the infection may take its start from the mucous membranes of the urogenital tract. Some infections may be transmitted by insects, which have taken up bacteria with the blood or secretions of a diseased individual or animal, or, having become contaminated externally by such, may infect an open wound by scraping the bacteria off their legs upon the exposed surface, or by the direct introduction of germs into the skin or accessible mucous membranes during the act of stinging or sucking. If meat containing bacteria be eaten, and if the animal while alive was affected by an infectious disease which also occurs in man, this particular disease may be transmitted to man, in case the bacteria had not been previously destroyed.

Bacteria arrive at the point of entrance, sometimes in association with chemically active substances, sometimes without such; the first is more likely to occur in the intestinal tract, the second in the respiratory passages and in the lungs; yet chemical substances may also find their way into the lungs with bacteria, and bacteria may enter the intestinal canal without the association of chemically active material.

The **harmful chemical substances which accompany the bacteria** may be either an *accidental admixture* of the food, or of the water used for drinking or washing or for the cleansing of wounds, or of the respired air; but they are more frequently the **products of the bacteria themselves**. All bacteria, even the non-pathogenic, produce within the medium in which they grow certain changes designated as fermentation

or decomposition processes, which stand in the closest relationship to their life-activity and reproduction. Among these products of chemical metamorphosis are many which are injurious to the organism of man and the higher animals, in that they are able to cause, in a manner similar to that of the poisons already mentioned, partly local tissue-degenerations and inflammations, partly blood-changes, and partly symptoms of general poisoning, which may be manifested in functional disturbances of the nerves, heart, or respiratory apparatus. The most important of these substances are the decomposition-products of albuminoid bodies, the **cadaveric alkaloids** or **ptomaines**, basic bodies, of which many are poisonous for man and are consequently called **toxins**. Further, *active albuminoid bodies*, the **toxalbumins**, occur, which are probably formed and cast off by the bacteria themselves (Buchner). For example, in decomposing meat the basic products, neuridin, cadaverin, putrescin, neurin, and methylguanidin, are formed; of these the last three are very poisonous toxins. The bacillus of typhoid fever forms a toxin (typhotoxin), which produces paralysis and stimulates the intestinal and salivary secretions; cholera bacteria form, in addition to penta- and trimethylendiamin and methylguanidin, also specific toxins, which irritate the intestine, destroy the coagulability of the blood, and cause muscular spasms. The tetanus bacillus produces tetanotoxin, a toxalbumin which causes violent muscle spasms; according to Roux, Yersin, Brieger, and C. Fränkel, the diphtheria bacillus, anthrax bacillus, typhoid bacillus, cholera spirillum, and the pus-cocci form toxalbumins.

When bacteria develop in large numbers in the tissues, and finally die, the soluble **substance** of the **bacterial cell**, mycoprotein, may cause irritation of the surrounding parts.

If **toxic bacterial products** are introduced in considerable quantity into the intestinal canal or into wounds at the same time with bacteria, symptoms of **poisoning** may be produced without a coincident infection, that is, without an increase of bacteria in the tissues. The same thing may also happen when poison-producing bacteria develop in the contents of the intestine or in wound-secretions or in necrotic lung-tissue, and so multiply as *saprophytes*. Such cases cannot strictly be regarded as infections, the disease is much more to be regarded as an intoxication; but in such cases a sharp line between infection and intoxication cannot be drawn, since bacteria originally growing as saprophytes not infrequently enter the tissues and multiply there.

**Intestinal intoxications** caused by *bacterial toxins* and *toxalbumins* occur especially when animal tissues or fluids are eaten in a state of decomposition due to the presence of bacteria; and to these intoxications belong the greater part of the affections termed *meat*-, *sausage*-, *fish*-, and *cheese-poisoning*. In these cases the particular poison is either taken as such with the food into the intestinal canal, or else is formed there. Likewise, decomposition and fermentation of the vegetable constituents of diet—as, for example, fermenting fruit-juices, cabbage, peas, beans, maize, rice, etc.—may have an injurious effect upon the intestine or even upon the entire organism, especially when eaten in large quantities or for a long period of time. The chronic disease known as *pellagra* or “*maidismus*,” occurring especially in Italy, Spain, Southwest France, and Roumania, is an example of such a condition. It is due to the eating of spoiled maize (Lombroso, Tuczek); and is characterized by gastro-intestinal disturbances, changes in the skin, disturbances of spinal and cerebral functions, and general marasmus.

If the bacteria which have entered the body through one of the above-mentioned avenues of infection are in a strict sense pathogenic, so that they give rise to an **infection**, they may increase first at the point of entrance, in the intestinal mucous membrane, in a wound, in the skin, etc. The **local effects** of their growth are dependent primarily upon the individual characteristics of the bacteria, as well as upon the peculiarities of the affected tissue. In general, the local action is characterized by tissue-degenerations, necrosis, inflammations, and new-formation of tissue, so that it is possible in many cases to determine the nature of the infection, that is, the species of bacteria causing the infection, from the character of the local changes. It is, however, difficult or impossible to determine in every case the exact mode of action of the multiplying bacteria; in general, it may be said that the processes of chemical metamorphosis excited by the multiplication of the bacteria produce certain changes in the tissue-cells, in that different substances of active chemical nature either kill the cells, or at least induce degenerative changes in them, or in part excite increased cell-activity. In the further development of the process the substances derived from dead and dissolving bacteria may also produce effects upon the surrounding tissue. In a certain sense, therefore, there occurs through the local growth of bacteria a *local intoxication*, which is of far greater significance than the *withdrawal of nutritive material* through the consumption by the bacteria of food substances. The latter is, however, not wholly without significance, inasmuch as the chemical changes produced by the bacteria in the tissue juices often render these unfit for the nourishment of the tissue-cells, so that the cells suffer even when no poisonous substances are produced.

The **participation of the entire organism** in a local bacterial infection may be very slight or wholly absent, so that the disease appears as a purely local affection (tuberculosis). In other cases the toxins and toxalbumins formed in the local focus of infection are absorbed into the body fluids (i.e., into the blood), and a **general intoxication** (*toxinaemia*) is produced; that is, poisonous effects are exerted upon the nervous system, sometimes upon the blood itself and upon the heart; and the poisons thus taken into the body may produce demonstrable changes in the internal organs, particularly in the excretory glands, at times also in the skin. In many diseases (tetanus, typhoid fever, streptococcus and staphylococcus infection, diphtheria) the symptoms of poisoning are especially prominent.

If healing does not take place in the primary seat of infection, the neighboring tissues may be involved by an **invasion of bacteria by continuity**. Very often the **bacteria gain entrance to the lymph-vessels or blood-channels** (*bacteriæmia*), and in this way are transported and spread over the entire body. The result of this *metastasis of bacteria* is the production of a **lymphogenous** or **hæmatogenous infection**; that is, *secondary foci of disease identical in character with the primary seat of infection* are formed at a distance from the primary focus. In certain diseases (tuberculosis, suppurations, plague) the number of **metastases** is usually very great, so that many parts of the body (lymph-glands, liver, lung, brain, muscles, bones, kidneys, etc.) may contain diseased areas. On the other hand, in other infections metastasis of bacteria from the original focus to other organs does not occur (tetanus, diphtheria), or the transported bacteria cause only changes of a milder type (typhoid fever).

During the transportation of bacteria through the blood-vessels, there is usually no increase of the bacteria in the circulating blood, the *blood serving only as a vehicle* to carry the bacteria to other parts of the body, multiplication occurring first at those points where the bacteria have come to rest. Nevertheless, in certain infections (anthrax) the *bacteria increase enormously in the circulating blood*, and in this way may cause damage to the blood itself. Through the obstruction of small blood-vessels by the multiplying bacteria, there may be added to the intoxication also local disturbances of circulation.

The metastasis of bacteria or toxic substances, or both, from a localized seat of infection, and the production thereby of secondary foci and symptoms of intoxication, give rise to the condition which is generally termed **sepsis**. According to the predominant symptoms there may be distinguished a *septicæmia* or *septicæmia*, a *pyæmia* and a *lymphangoitis*. Through the combination of both the latter with *septicæmia*, *septicopyæmia* is produced. Originally the designation **septicæmia** was applied to those cases in which a localized infection was associated with a *putrid intoxication* caused by bacterial poison or a *toxinaemia* without the spread of bacteria through the body. At the present time, according to the precedent set by Koch, Gaffky, and others, *septicæmia* is used to designate the condition characterized by the entrance of both bacteria and their poisons into the blood, a coincident *toxinaemia* and *bacteriæmia*; indeed, by many authors the pure putrid intoxication or *toxinaemia* is separated from *septicæmia*.

The term **pyæmia**, originally signifying a metastasis of pus through the blood, is at present employed to designate the condition in which the metastasis of bacteria gives rise to the formation of *metastatic abscesses*.

In **septicopyæmia** the symptoms of *toxinaemia* and *bacteriæmia* are combined with the formation of metastatic foci. **Lymphangolitis** is an *inflammation of the lymph-vessels and their surroundings* caused by transported bacteria.

Sepsis in its different forms is most frequently caused by the true *pyogenic organisms*, *staphylococcus pyogenes aureus*, and the *streptococcus pyogenes*, but similar conditions also occur in infection with the *pneumococcus*, *gonococcus*, *typhoid bacillus*, *colon bacillus*, *plague bacillus*, etc.

If **bacteria** are deposited secondarily in the body-passages which are lined with mucous membrane, as in the respiratory or urogenital tract, **they may multiply within these tracts** and produce their characteristic pathological changes. Likewise, they may **multiply also within the large body-cavities**, in the peritoneal, pleural, and subarachnoid spaces. In the case of an infection occurring in a pregnant woman, many varieties of **bacteria** (anthrax, symptomatic anthrax, glands, recurrent fever, typhoid, pneumonia, the pyogenic bacteria) may be **transmitted to the fœtus**.

The description given above of the course of an infection may be taken as a general type, and many infections run such a course (typhoid, pyæmia, erysipelas, plague, diphtheria, tetanus, tuberculosis, syphilis, leprosy, glands, actinomycosis, etc.); but there are also many deviations from this scheme. In the first place, it not infrequently happens that in an infection which in general runs a typical course, the primary seat of infection is not demonstrable, either because no changes occurred at the point of entrance, or the changes produced have since disap-

peared. Such forms of infection are known as **cryptogenic**; they may be **lymphogenous** or **hæmatogenous**. It is typical of many infections that the primary localization of the cause of the disease is not recognizable, so that *general symptoms occur before local changes are demonstrable*, and the tissue-changes occurring later have more the character of a *secondary localization of the poison of the disease*. This occurs especially in a number of infectious diseases, the causes of which are unknown to us; for example, in scarlet fever, smallpox, and measles; yet in many infections whose causes are known we are not always able to discover at what point the first multiplication of the bacteria occurs. Thus we know that in relapsing fever the spirilla are found in the blood in large numbers at the time of the fever, but the place of their multiplication is unknown to us.

Not infrequently a **secondary infection** may be joined to one already present. In many cases the association is entirely accidental, in other cases the anatomical changes produced by the first infection cause a local predisposition to the new invasion. To the first group would belong, for instance, a croupous pneumonia occurring in an individual suffering with tuberculosis; while the occurrence of an infection with cocci causing suppuration and septic intoxication, as in the case of wound-infections, in the course of typhoid, diphtheria, scarlet fever, dysentery, caseous ulcerating tuberculosis, etc., may be regarded as due to the production of local tissue-changes favoring the entrance of bacteria. According to the characteristics displayed by the recent epidemics of influenza in Europe, influenza is a disease which predisposes in a marked degree to secondary infection. In certain infections, as, for example, in many forms of purulent processes, the tissues may contain, even at an early stage, two or more varieties of bacteria—an **association of bacteria** or **double infection**.

It has been known for many years that during decomposition poisonous substances are formed. As early as 1852 *Beck* observed that ammonia hydrothionate, which occurs in pus and putrid ichor, possessed septic properties when injected into animals. *Pannum*, in 1863, obtained from decomposing material a *putrid poison*, that is, a body not destroyed by boiling and evaporation, which possessed an action similar to that of snake-poison and the vegetable alkaloids and caused in dogs salivation, dilatation of the pupils, diarrhœa, fever, and severe prostration. *Von Bergmann* and *Schmiedeberg* obtained from decomposing yeast a crystalline body, *sepsin*, which in animals produced the symptoms of a putrid intoxication. *Senator*, *Hiller*, and *Mikulicz* extracted from decaying tissue-masses by means of glycerin a substance which likewise possessed a septic action. *Billroth* called this poisonous substance *putrefactive zymoid*. *Selmi* endeavored to characterize all these substances more minutely, and obtained from different constituents of cadavers extracts, partly soluble in ether, partly in water, which he recognized as fixed bases of alkaloid-like character, and which he designated as **cadaveric alkaloids** or **ptomaines**. *Gautier*, *Etard*, *Zuelzer*, *Sonnenschein*, *Béchamp*, *Schmiedeberg*, *Harnack*, *v. Nencki*, *Otto*, *Angerer*, and others also found in decomposing tissues similar cadaveric alkaloids, which in experiments upon animals were partly inert, and partly toxic, producing in the latter case symptoms of poisoning similar to curare, morphine, and atropine. To *von Nencki* (1876) is due the honor of being the first to obtain a cadaveric alkaloid in its pure form and to establish its formula; this was accomplished in the case of collidin, obtained from decomposing glue and albumin, its platinum salt crystallizing in flat needles. Following *v. Nencki*, *Etard*, *Gautier*, and *Baumann*, and especially *Brieger*, have studied ptomaines, the last named having obtained a large number of them in a pure state and determined their physiological action. For instance, *Brieger* obtained from fibrin peptone a poison (peptotoxin) which in animals causes symptoms of paralysis and ultimately death. From decomposing horse-flesh he extracted three substances crystallizing in needles, namely, neuridin, neurin, and cholin, the second of which is markedly poisonous, and, like muscarine, causes salivation, disturbances of circulation and respiration, contraction of the pupils, and clonic convulsions. From fish-flesh he obtained, besides neuridin, three

other poisonous bodies: ethylendiamin, a substance similar in its action to muscarine, and a substance called gadinin. From decomposing glue and cheese he obtained the poison neurin, and from decomposed yeast dimethylamin.

The majority of ptomaines are not found in fresh tissues, and it is therefore very probable that they are derived from the splitting of chemical combinations present in the tissues. Thus it is probable that cholin is formed from the splitting of lecithin, and by the further decomposition of cholin the poison neurin is formed. Cholin and neuridin are, according to *Brieger*, demonstrable even in the fresh human brain.

After the poisonous nature of part of the ptomaines had been made known through the researches mentioned above, there was developed the *hypothesis* that the toxic symptoms observed in infectious diseases could be entirely, or in a great measure, ascribed to the action of the substances called toxins. Through the investigations of recent years (*Roux, Yersin, Buchner, Brieger, C. Fränkel*) it has been shown that **toxalbumins** play a more important rôle than the toxins, and can therefore be regarded as the *peculiar specific bacterial-poisons*. Our knowledge of active albuminoid bodies had been previously confined to the enzymes (pepsin, trypsin, ptyalin, diastase), which produce a hydrolytic splitting. The active poisonous albuminoids, the toxalbumins, have been made known for the first time through recent investigations of the infectious diseases. *Brieger* and *Fränkel* hold the view that the toxalbumins which produce symptoms of intoxication are formed by the action of bacteria from the albumins of the body juices. *Buchner*, on the contrary, believes that they are produced by the bacterial cell itself, and supports this view by the fact that the diphtheria bacillus in urine containing no albumin (*Guinochet*), and the tetanus bacillus in a solution of asparagin with mineral salts, are able to produce their characteristic toxalbumins. As in the case of the enzymes, the toxalbumins in solutions lose their activity at temperatures of 55° to 70° C. In the dry state they are able to withstand much higher temperatures. After injection into the tissues of an animal, toxalbumins do not act immediately, but after some hours or even after several days. In this respect they differ from ordinary poisons.

According to the experimental investigations of *Paclowsky*, staphylococci injected subcutaneously into guinea-pigs pass very quickly into the blood, and are found within a quarter of an hour in the liver, spleen, and kidneys. They remain in the blood for from six to twelve hours, and then disappear. In the organs where they multiply they may remain as long as fourteen days. Four to ten days before death they again appear in the blood. Streptococci produce in rabbits a general streptomycosis resulting fatally in from twenty to twenty-four hours.

Should the composition of the blood be altered and the blood and tissue-juices be contaminated by the continuous introduction of harmful substances, a condition may be produced which may be designated as a **dyscrasia produced by bacteria**. It is to be noted, however, that the term dyscrasia, which was formerly much used to designate changes in the constitution of the blood and lymph, finds at the present time but little usage.

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 See also § 6 and § 10.

§ 13. The **pathogenic moulds and fungi** belong, as do the Schizomycetes, to the non-chlorophyllaceous thallophytes. They occur in the human organism in the form of jointed or unjointed and sometimes branching threads or *hyphæ*, and short oval cells, the so-called *conidia*. At times they form fructification organs of peculiar structure. The single cells are much larger than those of the Schizomycetes, so that they may be seen with lower magnifying power. Outside of the body the moulds (*Mucorini*) develop as velvety films of different colors, on the surface of many organic substances and fluids, from the carbon-compounds and salts of which they derive their nourishment. The *yeast-fungi* (*Saccharomycetes*) are found chiefly in fluids containing sugar, and are the cause of the alcoholic fermentation of the same.

The spores or conidia, which are for the greater part formed in special organs of fructification, but may also be developed by a simple process of constriction of the ends of the *hyphæ*, pass into the air from the surface of the mould-film and may be widely scattered by the air cur-



rents. Likewise, yeast-cells may be carried about in the air, in the case of the evaporation of a fermenting fluid and the conversion of its residue into dust.

The Mucorini and the Saccharomycetes have a much less pathological significance than the Schizomycetes, in that only a few forms are able to multiply within the body, and those which do so multiply develop only in a very limited area, so that the disease remains a purely local one. Finally, they produce no poisons capable of affecting the organism as a whole through the blood or nervous system, but at the most only substances which cause changes in the tissues in the immediate neighborhood of the hyphæ. They can therefore produce only **local infectious diseases**.

The avenues of entrance for these organisms are, in general, the same as those for the bacteria. The development of moulds is almost entirely restricted to regions accessible from without. Very frequently they develop only in the necrotic material lying on the surface of the affected area of skin or mucous membrane or wound. Thus, for example, the external ear, through uncleanness, presence of cerumen, or of oil which has been dropped into the canal, may become the seat of a growth of moulds. These may develop also in necrotic areas in the lungs or in desquamated epithelium and food-remains in the mouth-cavity. Through the ingestion of fermenting fruit-juices, a further development of yeasts may take place in the stomach. Not infrequently, under other conditions, the stomach may contain yeasts in small numbers. The changes produced by the saprophytic development of the moulds and yeasts are in general insignificant, that of the latter being practically *nil*. Inflammatory changes may be set up by the moulds, as a result of the chemical changes produced in the materials affording them nutriment. The local action may be increased through the penetration of the hyphæ into the living epithelium, in that the hyphæ in this way enter into close relations with the epithelium and thereby take on the nature of a parasitic growth. Under certain conditions the moulds may even penetrate into the connective tissue, but their development there is of a very limited character. Only in very rare cases and under special conditions has a metastasis of conidia through the blood or lymph been observed. The deposit of conidia in other organs may be followed by a development of hyphæ, which may give rise to local degenerations and inflammation. From these secondary foci no further spread of the mould occurs.

The parasitic rôle of the moulds is most pronounced in the case of a few forms which are found in the skin, developing in the epidermis and its adnexa, the hair and nails, and giving rise to peculiar epithelial degenerations and inflammations of the papillæ and corium (favus, herpes tonsurans, pityriasis versicolor). In rare cases yeasts may also develop in the deeper tissues, and cause inflammation and tissue-proliferations.

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§ 14. The production of disease by animal parasites is most frequently brought about by the introduction of mature parasites, larvæ, or eggs into the intestinal tract through the medium of the food and drink or by unclean fingers. This is particularly true of those parasites whose habitat is in the intestine or the tissues located within the body; such parasites are accordingly designated as *Entozoa*. Parasites living in the outer tissues, as the skin, are termed *Epizoa*; they remain either on the surface of the skin or penetrate into the same from without. The passage of parasites from the intestine into the internal tissues and the changes thereby produced constitute the condition which is usually called, after the designation first used by Heller, an *invasion-disease*. The animal parasites for the greater part produce only local changes, but they can also cause symptoms of a general disease, particularly when the parasites increase in the body and are present in great numbers in the blood or certain tissues, or when they produce toxic substances.

The **parasitic protozoa** are partly harmless parasites, which develop in the secretions of the mucous membranes without causing pathological changes. Other forms, on the contrary, can penetrate into the living tissues, increase inside of cells, and give rise to local morbid changes, characterized chiefly by peculiar new-formations of tissue (coccidia-disease of the rabbit's liver, epithelioma contagiosum). Certain forms, which are probably to be classed as Sporozoa, increase in the blood, as inhabitants and destroyers of the red blood cells, and are the cause of the infectious disease known as malaria. It is not impossible that other infectious diseases, for example, small-pox, are caused by parasites belonging to the Protozoa.

The **parasitic worms** (*Nematodes*, *Cestodes*, *Trematodes*) occur in man, partly in the adult and fully developed sexual state, and partly in the larval state. In the first case they are for the greater part intestinal parasites, which obtain nourishment from the intestinal contents, rarely sucking the blood from the intestinal mucosa. Fully developed worms are also found in other regions, as in the blood- and lymph-vessels, bile passages, lung, pelvis of the kidney, and in the skin. The eggs or fully-developed larvæ produced in the body by parasitic worms are either cast out with the dejecta or, through active wandering or metastasis through the blood or lymph, finally reach other organs of the body, where they pass the first stage of their development. Here they remain, however, in a larval condition, and do not reach sexual maturity. The larvæ are capable of further development only when they have been taken into a new host.

The worms which reach their sexual maturity in the human body are taken in as larvæ through the food and drink. Their first stage of de-

velopment is passed in the great majority of cases in animals whose flesh is used for food; in other cases in certain of the lower animals not used as food. Others develop in water or damp earth or even in the human intestine, so that the embryos or eggs, which pass off with the dejecta, develop at once in case they are again introduced into the intestinal tract of man.

The worms which occur in man only in the larval condition (hydatids) develop from eggs which have come from sexually mature worms, which inhabit different animals. They are taken into the intestinal tract usually in the food or drink, but under special conditions eggs capable of development may be contained in the dust of the air, and, being inhaled and finally reaching the intestinal tract, complete the first stage of development.

The intestinal parasites for the greater part produce only slight disturbances, though they may cause mechanical irritation of the intestine. The presence of blood-sucking worms in large numbers (*Anchylostoma duodenale*) can cause anæmia. Those parasites which enter the tissues may cause in their vicinity mild inflammation and proliferation of tissue, which may produce more marked clinical symptoms when the number of the parasites (*trichina-larvæ*) in the tissues is very great. Others are of pathological importance, in that they reach a large size (*echinococcus* cysts) and thereby crowd aside and compress the neighboring structures.

Otherwise their pathogenic significance depends essentially upon their location. A parasite situated in the muscles or subcutaneous tissue may cause very slight symptoms, while one in the eye, medulla oblongata, heart, or blood-vessels may cause severe disturbances, and under certain conditions death.

The **parasitic arthropoda** (*Arachnida* and *Insects*) come to the human body partly from the outer world, partly from infected animals, and partly from infected human beings. They belong almost wholly to the Epizoa, which have their habitat in and upon the skin and accessible mucous membranes (lice, bedbugs, fleas, mites) or only occasionally take their nourishment from the skin (gnats, gad-flies, flies), a few multiply either in the skin (itch-mite) or upon its surface (lice). Flies and gad-flies occasionally lay their eggs upon the mucous membranes or surfaces of wounds, and from the eggs so laid larvæ may develop. The larva of an arachnoid (*Pentastoma denticulatum*) is alone found in the internal organs. In so far as the *Arachnida* penetrate into the tissues (epidermis, hair-follicles, and sebaceous-glands), they cause irritation and inflammation; the bite of insects that suck blood is also followed by an inflammation in the neighborhood of the puncture.

Attention has recently been directed to the possibility that mosquitoes, stinging flies, gad-flies, bed-bugs, lice, etc., may be the **conveyers of an infection**, in that bacteria or protozoa may by chance be attached to their bodies, or that in the act of sucking blood of an infected man or animal they may take up into their bodies either bacteria or protozoa and later convey them to other individuals. So far as experience goes, the danger of such conveyal is not very great in the case of the majority of the infectious diseases, since the bacteria thus taken up die after a time; yet it is probable that such conveyal does take place, as, for example, in plague, infection with pus-cocci, and anthrax. This method of conveyal is of chief importance in **malaria**, in that the *plasmodia* taken from the blood of infected individuals by mosquitos (*anopheles*) *undergo*

*further development in the body of the mosquito and produce a new generation, which through the bite of the mosquito is transferred to another individual, so that the spread of malaria is accomplished through mosquitos. Similar conditions exist also in the case of the tsetse-fly disease and Texas fever of cattle, the latter being conveyed by ticks. Further, it is claimed by Manson, Sonsino, and others that the infection of man with the filaria is also brought about through the agency of mosquitos.*

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## II. The Intrinsic Causes of Disease. Predisposition, Idiosyncrasy, and Immunity. Inheritance of Pathological Conditions and Diseases.

§ 15. The view is very frequently advanced that all pathological conditions are ultimately to be referred back to external causes. This is correct only in so far as the development of the human species, as well as that of the human individual, is not the result of a definite scheme of evolution of successive forms of animal life, but rather has been, and is still, purely the result of the action of external influences. If, on the other hand, the life of a single individual be alone regarded, there can be no doubt that for the origin of many pathological changes and diseases, certain qualities originating, partly in the congenital anlage and partly acquired in the course of life, play a rôle of very great importance.

The peculiarity of somatic qualities is shown in one of two ways: either in a changed condition of the power of the organism to resist external influences, or in that pathological changes of tissue or disturb-

ances of function arise independently of external influences. The first finds expression in those qualities of the body designated as *predisposition*, *idiosyncrasy*, and *immunity*; the latter in certain *inheritable, pathological conditions and functions of single tissues and organs or of the entire organism, which develop from congenital anlage without the aid of external influences*.

**Predisposition and immunity** play an especially important rôle in the origin of the infectious diseases. Man possesses an absolute immunity or insusceptibility to many of the micro-organisms pathogenic for animals; as, for example, the bacteria of swine-plague, swine-erysipelas, symptomatic anthrax. It is, therefore, to be inferred that the character of his tissues and tissue-juices does not favor the entrance and multiplication of the organisms causing these diseases.

On the other hand, the human race shows an especial predisposition or susceptibility for other diseases, such as small-pox, vaccinia, measles, and influenza, so that the great majority of human individuals in the course of life acquire these diseases. In the case of other diseases, as scarlet fever, pneumonia, typhoid fever, diphtheria, the susceptibility seems much less, but it is not possible to determine exactly to what extent the greater rarity of these diseases is dependent upon the fact that the individuals not affected are not exposed to the infection.

In the case of many infectious diseases, there is a greater susceptibility shown in childhood than in old age; as, for example, diphtheria, whooping-cough, and scarlet fever. Further, there are also variations in the degree of susceptibility at different times, as, for example, an individual may be exposed at certain times to measles without becoming infected, while at other times under similar conditions he may contract the disease.

In the case of many pathogenic organisms there appears to be necessary for the entrance of infection a certain *favoring condition or temporary increase of susceptibility*. As evidence of this may be taken the fact that in the human intestinal canal, and especially in the mouth and throat, as well as in the respiratory tract, pathogenic organisms (streptococci, staphylococci, pneumococci, tubercle bacilli) may be present without the occurrence of an infection. It may also happen that cholera spirilla may increase abundantly in the intestine without causing marked symptoms.

Such occurrences may be explained in part by a decrease or loss of virulence on the part of such bacteria, but this explanation cannot be applied to all cases. In many instances it must be assumed that the harmlessness of the bacteria is due to the ability of the tissues to hinder their entrance into the deeper parts. In some cases this may depend upon the structure and organization of the tissue, in other cases chemical substances may have a determining influence (see § 30). In favor of the first assumption lies the fact that tissue-lesions, which permit of the entrance of bacteria, bring about an infection. A *wound, therefore, in whatever way produced, forms a local predisposition*, and the disease, in such cases, bears the character of a **wound-infection**. Infections caused by pus-cocci, tubercle bacilli, tetanus bacilli, glanders, and anthrax bacilli are often of this character.

Other causes leading to an increased predisposition to infection are less easily recognized. It appears that severe *chilling*, "*taking of cold*," may have this effect; also *changes in the tissues due to preceding infectious or non-infectious local or general diseases*. In the case of intestinal infec-

tions (typhoid, cholera), *gastro-intestinal disturbances*, diminished acidity of the stomach contents, overloading of the intestines, retention of the contents, etc., play an important rôle. Not infrequently it is impossible to determine what causes have favored the production of an infection at a given time.

**Special predisposition** or special lessened resistance of the organism is also not infrequently shown to other injurious agents than those of infectious nature. Certain individuals are less able than others to stand external high temperatures, particularly if at the same time bodily labor is performed. Of the soldiers on a march only a fraction may suffer from heat-stroke, although all are under the same conditions. The altitude at which different individuals, during mountain ascents and balloon voyages, become sensible of the deficiency of oxygen, varies greatly. The after-effects of chloroform anæsthesia differ greatly in different individuals. Many individuals become exhausted through physical or mental labor at a time when in other individuals, under like conditions, no trace of such exhaustion is discoverable; and such influences operating daily upon a brain, in cases of especial predisposition, may lead to diseased conditions.

Occasionally certain individuals show a sensitiveness toward particular external influences, which is wholly anomalous to that usually observed, so that symptoms of disease may be caused by influences which ordinarily do not affect the majority of mankind. Such a peculiar sensitiveness is designated **idiosyncrasy**. It is exhibited particularly in reference to certain chemical substances, in that certain articles of food or drink regarded as harmless act upon such persons as poisons. The eating of fresh fruit or sugar or salad produces, in certain individuals, nausea and vomiting. Others have an aversion to partaking of dishes prepared from liver or kidneys, and become ill if they overcome this aversion and eat these foods. Others still, after eating crawfish, lobster, strawberries, raspberries, morels, or asparagus, are affected with urticaria, a disease characterized by an eruption of itching wheals, colic, and vomiting. Not a few persons are unable to drink boiled milk without unpleasant results therefrom. Alcohol, even in very small doses, may in certain individuals cause marked excitation, or narcosis, or remarkable disturbances of the vaso-motor system. The drinking of cocoa may cause cardialgia and dyspeptic symptoms. Doses of morphine or chloroform, which are borne by the majority of mankind without injury, may cause in certain individuals severe symptoms or even death. Some individuals show a high degree of sensitiveness, on the part of the mucous membranes of the respiratory tract, to the pollen of certain grasses, so that during the time of the hay-harvest the inhalation of the pollen which is widespread through the air gives rise to a catarrhal condition of the nose and conjunctiva, often of the larynx, trachea, and bronchi, which in severe cases may be associated with asthma and fever. These conditions are known as *hay-fever*, *hay-asthma*, or as pollen-diseases. Disinfecting fluids, corrosive sublimate or carbolic acid, in solutions which are ordinarily borne without discomfort, may, when applied to the skin of certain individuals, cause not only local disturbances of sensation and inflammation, but under certain conditions may excite an eczema which spreads over a large part of the body.

On what the peculiar idiosyncrasy in individual cases depends is not clear. In many cases an especial excitability of the nervous system or of certain parts of the same may be regarded as the cause of the phe-

nomenon. In acquired idiosyncrasy, as, for instance, that exhibited toward certain articles of food, psychical factors may play a part.

The great importance of the part played by natural predisposition and immunity in the origin of infectious diseases has not only been made evident by the study of the spread of epidemics among men and animals, but has received also abundant confirmation by numerous experimental investigations. If, for example, a mixture of different bacteria be injected into an animal, only a part of these will develop and produce tissue-changes; the others die. If the same mixture be injected into an animal of a different species, the bacteria which develop are not the same as those in the first case. Further, a certain form of bacteria which when inoculated into a certain species of mouse invariably causes death, may, when inoculated into another mouse of different species, be without effect. Mice are very susceptible to anthrax, rats are nearly immune. The poison of the so-called septicæmia of rabbits kills with absolute certainty rabbits and mice; guinea-pigs and rats are immune to it, while sparrows and pigeons are susceptible. The spirilla of relapsing fever may be successfully inoculated only into apes. Gonorrhœa, syphilis, and leprosy cannot be successfully inoculated into any of the lower animals.

In the same species, different animals of different ages exhibit differences of susceptibility toward certain organisms. Young dogs are easily infected with anthrax (*Koch*), old ones are not.

Different experiments have shown that an immunity toward a certain infection may be destroyed by suitable action upon the tissue (*Sirotnin*, "Die Uebertragung von Typhusbacillen auf Versuchsthiere," *Zeitschr. f. Hyg.*, i., 1896). According to *Royer* ("Contribution à l'étude expérimentale du charbon symptomatique," *Revue de méd.*, 1891), the natural immunity of rabbits and pigeons against symptomatic anthrax may be overcome, if the non-pathogenic *Bacillus prodigiæ* be inoculated at the same time with the bacillus of the disease. According to this investigator, the decomposition product of the *prodigiæ* that is soluble in glycerin exerts a modifying action upon the organism.

According to *Gottstein* ("Beiträge zur Lehre von der Septikämia," *Deut. med. Wochenschr.*, 1890), guinea-pigs may be made susceptible to the subcutaneous inoculation of chicken-cholera bacilli, to which they are naturally immune, through the injection of substances which destroy the red blood-cells, such as hydracetin or pyrogallol. This investigator concludes, therefore, that toxic substances, which render either man or animals more susceptible to infection, act chiefly through a dissolution of the red corpuscles. According to *Leo* ("Beiträge zur Immunitätslehre," *Zeitschr. f. Hyg.*, vii., 1890), white mice which are immune to glanders may be made susceptible to inoculations with the bacilli of this disease by mixing with their food a small quantity of phloridzin, which causes a toxic diabetes.

According to *Canalis* and *Morpurgo*, pigeons may be made susceptible to anthrax through starvation. According to *Lode*, chilling of the body increases the susceptibility to infection.

The especial diseases to which the *new-born* so frequently succumb are, aside from the conditions acquired during intra-uterine life, dependent partly upon a pathological weakness of the entire organism (especially in case of premature birth), and partly upon the surrounding conditions. Asphyxia, which is of such frequent occurrence, may arise either as the result of bodily weakness or of pathological influences exerted during delivery. Infectious diseases may be acquired through the stump of the cord or through the accessible mucous membranes and respiratory tract during birth. Hemorrhages are dependent partly upon traumatic influences exerted during birth, partly upon disturbances of circulation and upon infections.

Children are, as has been shown by medical experience, *more susceptible to many infections* than adults; particularly so in the case of whooping-cough, diphtheria, measles, and scarlet fever. The skin of infants also offers less resistance to the entrance of pus-coeci than that of older individuals. In this connection it should be noted that the slight susceptibility or the immunity of many adults is dependent upon the fact that they owe their immunity to attacks of such diseases during childhood. Further, it should be remarked that children are more exposed to certain infections, for instance, tuberculosis, than are adults.

In *later life* hemorrhages, softening of the brain, cardiac degenerations, cancerous growths, and the formation of gall-stones are of especially frequent occurrence. The disease of the arteries known as arteriosclerosis, and also gout, may appear even in the late years of middle life. The *predisposition in old age to certain diseases* depends in part upon degenerative processes, associated with premature senility of the tissues; in part also upon the fact that certain influences, which the years bring with them, grad-

ually accumulate, so that finally the changes which they produce become so prominent that they lead to functional disturbances, and thereby to recognizable morbid conditions. Moreover, it is to be remarked that many pathological symptoms of old age are secondary diseases, which become apparent only after other tissue-changes have reached a certain degree. For example, senile hæmorrhages, senile gangrene, degenerations of the brain and heart are dependent upon disease-processes occurring in the arteries.

The *predisposition of the sexes* to certain diseases depends, in the first place, upon the especial structure and function of the sexual apparatus. The conditions of pregnancy and the puerperium offer an especially favorable field for many diseases, as, for example, for infection through wounds. Moreover, the different relations of the sexes to many diseases may be explained by differences in the modes of labor and in the habits of living of the two sexes.

*Differences of predisposition of different races* are shown particularly in regard to malaria and dysentery, toward which the negro in general shows less susceptibility than the European. The Japanese are said to be more susceptible than the European toward beri-beri.

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§ 16. Among the morbid conditions originating from intrinsic causes, that is, without the aid of specific extrinsic influences, and which either appear spontaneously or are developed through any external influence whatsoever, there may be distinguished different groups; namely, one in which the body as a whole—the constitution—is involved; another in which only a part of the body as a system or an organ is affected; and, finally, a third in which only a part of an organ presents functional or anatomical changes of a pathological nature. It must be noted that there is no sharp dividing line between these groups, inasmuch as local pathological changes may be associated with constitu-



tional conditions. Further, it is often very difficult or impossible to determine exactly what part intrinsic and what part extrinsic causes have taken in the production of such pathological conditions, inasmuch as the force of the external influence which has called the pathological process into activity cannot be estimated with certainty.

Among the constitutional diseases arising from intrinsic causes are to be mentioned, first, the development of dwarfs and giants, disturbances of growth, the first of which is marked by an under-development of all the parts of the body, both of the skeleton and the soft parts, while the second is characterized by a growth exceeding that of the ordinary individual. It cannot be doubted that both dwarf and giant growths are often purely dependent upon a congenital tendency; but the same effects can be produced, at least in so far as the inhibition of growth is concerned, by harmful influences exerted during the period of development and growth. It cannot always be told with certainty whether an abnormal bodily growth is dependent upon a congenital tendency or upon pathological influences during the period of growth, as, for example, upon disturbances of growth due to disease or loss of the thyroid gland.

The same difficulty is presented in cases in which the body has attained full development of stature, but manifests a **general feebleness of constitution**, as shown by its inability to withstand a great variety of external influences. Such condition may arise either from congenital defective and weak anlage or from harmful influences which have attacked the body during intra- or extra-uterine life; or further, congenital weak anlage and external weakening influences may have affected the development of the individual in an equal measure.

A further constitutional peculiarity, which is founded upon a special congenital anlage, is **corpulence** (*obesity, adipositas, lipomatosis universalis*), a condition in which fat is deposited in an excessive amount, either in the tissues normally containing fat, or further, in regions which normally contain no fat, as, for example, beneath the endocardium or between the muscles. The increased deposit of fat is ultimately to be referred to a disproportion between fat-production or fat-supply and fat-consumption, the pathological increase of fat being at one time dependent upon an abnormal increase of fat-production, at another on a decrease of fat-consumption. Daily experience teaches that the energy with which metabolism goes on in the body differs greatly, and changes also at the different periods of life, so that the normal amount of nourishment tends at one time to fatten, at another time does not.

In the pathological condition termed obesity, which in part rests upon a congenital tendency, the energy of the protoplasmic forces of destructive metamorphosis is weakened, so that an abnormal amount of fat is deposited, even when only a moderate or even a decreased amount of nutritive material is supplied to the tissue.

**Gout**, like obesity, is also a constitutional disease, which is chiefly dependent upon a congenital anlage and is produced essentially by intrinsic causes. The exact nature of the disease is not yet known. It is characterized by deposits of uric acid in the tissues. According to Garrod and Ebstein, the acute attacks of gout are caused by an accumulation of uric acid which has its origin either in the kidneys or in local conditions. On the other hand Pfeiffer holds that the essential feature of the gouty tendency consists in the fact that the uric acid is produced in a form which is soluble only with difficulty. According to von

Noorden, the formation and deposit of uric acid is only a secondary process, which is induced by the presence of a certain ferment having only a local action, and is consequently not dependent upon the amount or character of the uric acid formed in other parts of the body.

**Pathological changes arising in single systems and organs from intrinsic causes** may occur in any part of the body, and may involve an entire system or organ, or only a part of one.

In the **skeleton** there may occur abnormal development of single parts, as, for example, an abnormal smallness of the extremities (micro-melia) or of the head (microcephalus) in contrast to the size of the trunk; an abnormal over-development of a bone or group of bones (macrocephalus, macrodactylism, giant growth of a finger, entire foot, or of an extremity); malformations of the extremities (cleft-hand, cleft-foot, etc.). Occasionally supernumerary bones, as carpal bones or phalanges, may develop, giving rise to supernumerary fingers. Further, there may be developed atypical formations, such as bony out-growths (exostoses, hyperostoses), which may extend over the skeleton to a greater or less extent, originating either spontaneously or following some traumatism.

In the **muscular system** there occur particularly pathological bony formations, either single or multiple (myositis ossificans), which, in the period of childhood, occasionally lead to a progressive stiffness of the muscles, through the transformation of muscle into bony plates.

In the **vascular system** there occur either gross anatomical changes, such as abnormal branching of the arteries, pathological development of the heart, or finer changes, which reveal themselves through some abnormal action on the part of the circulatory apparatus or through a tendency to hæmorrhages (*hæmophilia*) which take place spontaneously, that is, without our being able to demonstrate the action of some injurious influence upon the heart or blood-vessels.

During the development of the **central nervous system** there may occur primary disturbances, which in part may manifest themselves only through some *pathological disturbance of function* or some *special predisposition to disease*, while others are distinguished by *gross anatomical changes*, such as abnormal smallness of the brain (micrencephalon) or of the spinal cord (micromyelia), defective development or absence of particular parts (see chapter on malformations), misplacement of the gray matter (heterotopia of the gray substance), abnormal formation of cavities (syringomyelia), or abnormal formations of neuroglia. These disturbances may involve the functions of the sensory organs and the motor centres, and even to a greater extent the psychical processes. The morbid conditions known as idiocy, epilepsy, periodic and circular insanity, hysteria, neurasthenia, as well as paralysis, mania, melancholia, and dementia, may have their origin in a congenital predisposition. Recently the tendency to crime has also been ascribed to a congenital predisposition, and Lombroso, in particular, has endeavored to prove that the man who lives only through crime and for crime, the *Homo delinquens*, is a congenital criminal—that is, a man who suffers from bodily and mental abnormalities, who possesses other physical and psychical characters than the normal man or even than one who is simply mentally unbalanced, in that he presents the symptoms of a form of degeneration tending in a well-defined direction. According to Lombroso, a subnormal development of the anterior half of the cranium, associated with a corresponding lack of development of the anterior portion of the

cerebrum, in connection with an over-development of the posterior portion, produces a feeble development of the intelligence and of the moral sense, and favors a strongly developed instinct-life. Benedikt even goes so far as to maintain that the criminal possesses a peculiar configuration of the cerebral convolutions, similar in type to those of beasts of prey.

The views of Lombroso and Benedikt have met with much opposition, and have been attacked as incorrect. There can be no doubt that there does not exist a degenerate species of the human race, which is characterized by such anatomical peculiarities as to make it possible for us to distinguish a class of *Homo delinquens* from that of *Homo sapiens*. All the somatic peculiarities regarded as characteristic of the criminal type—as, for example, the beast-of-prey type of cerebral convolutions, slightly developed frontal brain, receding forehead, massiveness of the lower jaw, prognathia, asymmetry of the cranium, marked prominence of the arcus superficialis and arcus frontalis, pathological conformations of the skull, etc.—while relatively frequent in criminals, are also far from being infrequent in normal men. On the other hand, it is not to be doubted that the tendency to crime is very frequently dependent upon a congenital predisposition having its seat in some special organization of the central nervous system. In this respect the criminal resembles the insane individual; further, mental diseases—for example, epilepsy and hysteria—are often observed in criminals.

*Pathological cerebral functions* may develop primarily in individuals possessing such morbid predispositions—that is, without external influences playing any part in the production of the disturbance, so that the person concerned may manifest pathological disturbances of cerebral functions without the concurrence of any external injury, either during the period of development and growth or later. On the other hand, in other cases, external influences—such as mental work, sorrow, care, psychical irritation, disease, etc.—are the causes which give rise to the particular illness—that is, to the occurrence of pathological brain or spinal-cord functions. In these cases the inherited tendency consists only in an abnormal weakness, a predisposition to disease of the central nervous system, so that insignificant influences which would produce no recognizable effects upon a normal individual are sufficient to excite the morbid phenomena. Since many influences, as diseases, infections, psychical irritations, are adequate under certain conditions to produce mental diseases in individuals who must be regarded as normal, it is clear that in many instances it is difficult and often impossible to determine what part the intrinsic causes—the inherited predisposition—and what part the extrinsic causes have had in the production of a disease of the central nervous system.

In the case of the **peripheral nerves**, it is especially their connective-tissue elements which often take on a pathological activity of growth under the influence of intrinsic causes. This activity may manifest itself partly in the form of diffuse thickenings (fibromatosis of the nerves), which are situated either along the course of those nerves large enough to be dissected with the knife or along the finer nerves, often in large numbers through the entire nervous system, and occasionally involving the entire territory of the peripheral nerves, the skin being most frequently affected (multiple fibromata of the skin). In individual cases the fibromatosis of the nerves is associated with an increase in the number of nerve-fibres, so that within a given area of nerve-distribution there will be found a great increase of nerve-fibres, thickened through a

pathological increase of the endoneurium and for the greater part twisted and wound into serpentine forms (cirroid neuroma, plexiform neuroma).

Among the **pathological conditions of the visual apparatus** are to be mentioned in particular dyschromatopsia and achromatopsia, congenital partial or total color-blindness, which are frequently spoken of as Daltonism, and are characterized by a want of perception for certain colors (most frequently for red and green) or for all the colors. In this same category belongs further the typical pigment degeneration of the retina, in which there occurs a peculiar spotted, black pigmentation of the retina, associated with a diminution of central sharpness of vision and light-perception, with a narrowing of the visual field. Finally, certain forms of myopia, also albinism (absence of pigment in the choroid), the latter condition also involving the structures of the skin, are to be considered in this connection.

Of intrinsic conditions of the **auditory apparatus** deaf-mutism is of chief importance; this condition, in part at least, is dependent upon a primary disturbance of development. Further, certain malformations of the external ear fall into this class.

In the **skin and subcutaneous connective tissue** new-growths may develop from congenital anlage, consisting of proliferations, sometimes of connective tissue, at other times of epithelium. They often involve particular parts of the skin, as the cutaneous nerves, blood-vessels, lymph-vessels, or the adipose tissue. When occurring as extensive thickenings of the skin and subcutaneous tissue, they constitute the foundations of the conditions known as fibromatous, neuromatous, hæmangiomatous, lymphangiomatous, and lipomatous elephantiasis. As circumscribed growths they are known as birth-marks, fleshy moles, lentigines, freckles, and tumors of the blood- and lymph-vessels. The epithelial hypertrophies give rise to those conditions designated as fish-scale disease or ichthyosis, ichthyotic warts, and cutaneous horns.

In addition to the pathological conditions which have been mentioned, there are also **malformations of the body** (see chapter on malformations) or **also of internal organs** which must be regarded as primary—i.e., which are not produced by injurious influences exerted upon the developing fœtus. Finally, many forms of **tumors** (see chapter on tumors) are to be placed in this class, particularly those which are found to be already developed at birth or which develop during childhood.

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 See also § 17.

§ 17. **The origin of diseases attributed to intrinsic causes**—that is, of diseases in which extrinsic influences are either entirely absent during both intra- and extra-uterine life, or are of significance only as a source of irritation sufficient to excite into development pathological tendencies already present in the body—may be explained in two ways: *Either the pathological peculiarities of the individual concerned are inherited from the ancestors, or they are developed from the seed, i.e., from the individual sexual nuclei that have copulated or from the segmentation nucleus resulting from their union.*

**The inheritance of pathological qualities** is a fact clearly shown by clinical observations, inasmuch as many of the examples of diseases due to intrinsic causes which are cited in § 16 also appear as inheritable characteristics in certain families. In some cases these characteristics are transmitted from the parents to the children, in other cases the grandchild may exhibit pathological peculiarities of the grandparents, the parents themselves remaining exempt; finally, in other cases the pathological peculiarity may be manifested in individuals of the collateral branches, as from uncle to nephew. Dwarfishness and giantism are pathological peculiarities which frequently characterize certain families. Six fingers, cleft-hand and cleft-foot, hare-lip, dextrocardia, birth-marks, multiple exostoses, fibromatosis of the nerves, and multiple neurofibromata may appear in families for many successive generations.

Congenital hæmophilia is also an inheritable condition, which is ordinarily transmitted through the daughter to a male grandchild, the daughter not showing the disease. There may occur, however, a direct transmission of hæmophilia from parents to children. Partial or total color-blindness also occurs as an inheritable family disease, especially affecting the male members, and like hæmophilia is transmitted through the female line, which does not suffer, to the male descendants. The typical pigment-degeneration of the retina, myopia, deaf-mutism, certain forms of progressive muscular atrophy, and polyuria (Weyl) are also inheritable.

According to Gairdner and Garrod, in about ninety per cent of the cases of gout there is a family history of the disease.

Of the pathological conditions of the nervous system many are inheritable; to these belong especially periodic and circular insanity, epilepsy, hysteria, congenital insanity, and to a somewhat less extent

melancholia, mania, delusional insanity, and alcoholism. Progressive paralysis, the deliriums, and the conditions of nervous exhaustion are but slightly influenced by heredity (Kraepelin). Hagen estimates the number of hereditary insane at 28.9 per cent, Leidesdorf at 25 per cent, Tigges at over 40 per cent of all cases, while Forel holds that 69–85 per cent may be accounted for by heredity.

In the most severe forms of hereditary degeneration the pathological condition itself is inherited, but more frequently the predisposition to disease is alone inherited and the morbid condition itself is developed through the action of extrinsic harmful influences upon the central nervous system. The character of the disease in the descendants may be the same as in the ancestors (*identical heredity*). More often the character of the disease is changed (*transformational heredity*), not infrequently in the sense that the severity of the condition increases from generation to generation (*degenerative heredity*).

According to Morel, there may appear, for example, in the first generation, nervous temperament, moral depravity, excesses; in the second, a tendency to apoplexy, severe neuroses, alcoholism; in the third, psychological disturbances, suicidal tendency, intellectual incapacity; finally, in the fourth, congenital idiocy, malformations, and arrests of development.

The occurrence of **inheritable diseases** is by no means remarkable; it is a well-known fact that in a family not only the peculiarities of race, but also of that particular family are inherited, and that very often the characteristic qualities of either parent or of both recur in the children. As a hypothesis for the explanation of heredity, it is only necessary to assume that the peculiar quality under consideration represents not merely a somatic change accidentally acquired during the life of the ancestor, but much rather a quality of the ancestor developed from a **congenital anlage**. Diseases which in a normal individual arise only under the influences of some external injurious influence are never in a true sense inherited (compare § 19), but only those *pathological conditions existing in the germ* are to be regarded as examples of true inheritance. If a certain disease, as, for example, a mental disease or myopia, is the product of a special inherited predisposition plus the effect of injurious influences which have acted upon the body during life, only that part can be transmitted which has its seat in some peculiar congenital anlage, but not that caused by external influences—the acquired condition cannot be inherited.

In *direct inheritance*—i.e., in that form of inheritance in which parental qualities are transmitted to the child—the transmission of normal as well as of pathological qualities is possible only when both sexual cells, in the condition in which they combine, contain the potentialities of the characteristics of both parents, in so far as these characteristics are transmissible. The product of the union of the sexual cells—the segmentation-cell—must, therefore, contain within itself both the paternal and maternal qualities. Since the sexual cells do not represent a product of the body developing during the course of life, but are rather to be regarded as independent structures, which at an early period of development are separated from the other parts of the body (that is, from the somatic cells) into special organs, where, protected and nourished by the body to which they belong, they lead an independent existence; the only possible explanation for the phenomenon of inheritance is found in the hypothesis that the individual sexual cells contain, from the time of their origin onward, the potentialities of the same qualities which appear

in the body in which they dwell. Both the sexual cells and the body itself, therefore, inherit in general the same qualities from the ancestors. Since in the act of fructification only the nuclei of the sexual cells—that is, parts of the same—come to copulation, we are compelled further to assume that the nuclei are the bearers of inheritable qualities, and the peculiarities of the individual arising from the combination of the sexual nuclei have their foundation in the organization of the nuclei.

The appearance in the descendants of normal or pathological characters belonging to the collateral relatives (uncle, great-aunt, or cousin), but which are not present in the parents, is known as *collateral inheritance*. This phenomenon is explained by the hypothesis that the sexual cells, in their origin, received characteristics which the bodies of the parents did not receive, or which, at least, did not undergo development and manifest themselves in the parental bodies, whereas in certain relatives they did become manifest.

The appearance in an individual of normal or pathological characteristics which were wanting in the parents, but were present in the grandparents or great-grandparents, is known as *atavistic inheritance*. This phenomenon is explained by the hypothesis that given characteristics of the grandparents or great-grandparents were transmitted to the sexual cells of the son, or of the son and grandson, without developing in the body of the first, while the quality thus remaining latent became again manifest in the grandson or great-grandson.

The attempt has been made to give to the atavistic mode of transmission—which is of frequent occurrence and is usually confined to the immediate generations of ancestors—a wider significance in pathology. Thus it has been proposed to explain the occurrence of many newly arising pathological conditions, which appear similar to certain somatic qualities possessed by remote animal species in the ancestry of man, as a reversion to the type of these ancestors. For example, microcephalus and micrencephalus have been explained as a reversion to the ape type; and Lombroso is inclined to regard the *homo delinquens* as an atavistic phenomenon. There can be no doubt that certain writers have gone too far in this respect and have mistaken certain acquired pathological formations or new germ-variations (compare § 18) for atavistic conditions. Aside from the question of reversion to the type of the nearest generations of ancestors, atavism plays but an insignificant part in pathology, and it can really be employed only in the explanation of pathological formations in which the tissues show a certain fluctuation of behavior, so that not rarely formations arise which in phylogeny or ontogeny represent stages of the then normal conditions. In this category belong, for example, the occurrence of certain forms of the ear, supernumerary ribs, nipples, or mammary glands, and the development of certain muscles which are found in the most closely related mammals.

It is held by many writers that *in individual cases, acquired pathological conditions may, under certain circumstances, be transmitted to the descendants*. Some even affirm the possibility of hereditary transmission of deformities caused by injury, and regard such transmission as proved in certain cases. In support of their view they believe that they can refer to the hereditary transmission of birth-marks, malformations of the fingers, myopia, mental diseases, predisposition to tuberculosis, etc., as examples, according to their assumption, of diseases which appeared in the first instance as acquired, and which were then transmitted to the descendants. Further, they hold that they can point to observations on animals, of which numerous accounts are found in the literature, as giving evidence that injuries may cause deformities which are later transmitted to the offspring.

An unprejudiced examination, however, of the material collected in support of this view shows that *observations which establish the hereditary transmission of pathological characteristics acquired in the individual do not exist*. The alleged proofs are found in part to be based upon inaccurate observations, in part upon incorrect inferences drawn from accurate observations. For example, the assumption that the occurrence of a birth-mark in a child in the same region of the skin as that in which the mother has a scar is a proof of inherited deformity is wholly in the wrong, inasmuch as birth-marks and scars represent two entirely different pathological processes. If, among the descendants of a man who suffered from some form of mental disease and who showed this disease only after a certain age through the perversity of his actions, there appears an inheritable disease of the central nervous system, or if we note a similar occurrence in the case of myopia, we cannot conclude from such observations that the disease of the ancestor was purely an acquired condition. The term *acquired*, in the biological sense, can be applied only to that which in the course of the life of an individual arises purely from extrinsic influences, but not to a quality, the anlage of which existed already in the germ-cell, although this quality did not become manifest until excited to development by extrinsic influences. Should there appear in a family inheritable mental diseases or hereditary myopia, the first case of such diseases may have already been due to some pathological alteration of the germ, although no manifestations of the disease occurred until some of the outside influences of life excited it to activity, and so rendered possible the recognition of the pathological condition. The particular pathological condition in this case cannot, therefore, be regarded as a purely acquired disease.

The observations of *Broen-Séguard* that guinea-pigs, in which epilepsy has been experimentally induced, can transmit the condition of epilepsy, have been shown by *Sommer* to be incorrect, in that the condition is not a true epilepsy, but a reflex epilepsy, and is not transmitted.

Against the occurrence of an inheritance of acquired pathological conditions is the simple consideration that the human race, which is exposed to so many injurious influences, and whose individual members suffer so frequently from disease and mutilations, would very soon arrive at a state of extreme misery and stunted growth and would eventually perish were only a small part of the acquired diseases transmitted to the descendants. Further, the origin of man and animal forms reproducing through germinal cells is in itself an argument against the possibility of the transmission of qualities acquired by the individual.

The act of fructification—that is, the first step leading to the production of a new individual—is accomplished by the copulation of the sexual nuclei—that is, of the nuclei of the ovum and spermatozoön. According to the researches of the last decades, there can be no doubt that *these nuclei are the bearers of the hereditary characteristics of the parents*, and that the individuality of the copulating nuclei is inherent in the organization of the same. It is impossible to conceive in what manner processes taking place in the body cells can produce in the sexual nuclei, which lie within special cells in the sexual glands, such alterations of organization that they shall contain in potential form the acquired characteristics of the body and transmit them, after copulation has occurred, to the descendants.

*Delage* was able to fructify non-nucleated portions of the eggs of echinoderms, annelides, and mollusks with spermatozoa (merogony). He regards the union of the nucleus of the spermatozoön with the protoplasm of the egg as the essential feature of fructification. This is not applicable to the ordinary method of fructification, but only shows that in exceptional cases the entrance of the spermatozoön into the protoplasm of the egg is sufficient for the setting-up of further development, and that the nucleus of the spermatozoön entering into the egg without uniting with the nucleus of the latter exercises an especial influence upon the protoplasm of the egg.

*Darwin* in his time represented the view that acquired characteristics could be transmitted to the descendants, and endeavored to make such phenomena intelligible by the theory that molecules from all the cells of the body contribute to the formation of the germ-cells, and that, consequently, alterations of the organism can be transmitted to the germ-cell. Nevertheless, there occur in the writings of *Darwin* statements which not only do not agree with this opinion, but directly contradict it.

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- See also § 16 and § 18.

§ 18. As has been explained in § 17, *inherited diseases are always such as have at the very first developed from intrinsic causes, that is, from certain anlage in the germ-cells; or at least are diseases in which the predisposition thereto is a congenital characteristic.* Conversely, the statement may be made that *all normal or pathological qualities in the germ-cells are inheritable.*

Consequently, the questions as to the primary origin of inherited diseases are identical with the questions concerning the nature of the causes of intrinsic diseases—i.e., concerning the origin of those pathological qualities which we regard, when appearing later, as arising spontaneously and dependent upon some congenital anlage.

The **first appearance of new pathological characteristics which are inheritable** may be dependent upon the fact that as a result of **sexual procreation**—i.e., of the union of two sexual nuclei, one of which is the bearer of the transmissible qualities of the father, the other of those of the mother—**new variations** are constantly arising, so that the child is

never exactly like one parent; but, on the other hand, in addition to the qualities which the parents offer, it possesses also new qualities. Even if we assume that the sexual nuclei at times contain in potential form exactly the same characteristics as those of the parents, the product resulting from the copulation of these nuclei would present a certain degree of variation. In such a case, however, the differences between the children of such parents would be but slight. As a matter of fact, the different products of the same parents may show an infinite variety, by reason of the fact that the germ-cells themselves contain further a mixture of the transmissible characteristics of the paternal and maternal ancestors, and that this mixture is never the same in the individual germ-cells.

In accordance with this is the fact that the children of a certain family always present important differences in both physical and mental qualities. A marked resemblance occurs only in the case of twins arising from one egg—i.e., when the process of development of both children has started from the same act of copulation.

The **embryonal variations resulting from the mixture of two individually different hereditary tendencies** can find their expression in the most varied qualities of the body and mind of the developing child. If these do not deviate in a marked degree from the characteristics which the different members of the family show, the conditions are regarded as normal and ordinarily receive no especial attention. If, on the contrary, important differences of character are produced, the occurrence attracts greater attention; and, according to the value which it has for the individual concerned, is regarded at one time as something favorable, at another time as something unfavorable, something pathological. When small, weak parents produce children who develop into large and strong individuals, or when the intellectual capacity of the children surpasses that of the parents, the occurrence is regarded as favorable. If, as actually happens, a genius in any branch of human knowledge or skill suddenly appears within a family, without any evidence of an especially marked mental development in the ancestors, the phenomenon would attract general attention and be regarded as a fortunate event. But if, on the other hand, strong parents beget children who are weak or physically defective, or if they show a mental development inferior to that of their parents, or if they show a complete stunting of a part of their mental faculties, *the newly appearing variation is regarded as abnormal, pathological.*

If we consider the experiences which the pathology of man and animals furnishes, the assumption seems fully warranted that of the **transmissible pathological conditions and predispositions**, very many, perhaps the majority, **are referable to a variation of the germ based upon the amphimixis.** For example, the group of hereditary pathological conditions and predispositions of the central nervous system, hereditary myopia, hæmophilia, pigmentation of the retina, and polydactylism may arise in this manner. If such abnormal characteristics show themselves repeatedly in the children of the parents, who are themselves normal and have healthy ancestors, it may be assumed that the germ-cells of the parents, though individually normal, have through their union given rise to a pathological variation. This hypothesis becomes substantiated when one or both parents produce normal offspring through copulation with other individuals.

Besides the variations which are the result of normal sexual repro-

duction, it is very probable that pathological germ-variations which lead to the development of transmissible pathological qualities may also arise through the action of **injurious influences upon the sexual nuclei or the segmentation nucleus**; or else that the **process of copulation**—that is, the union of the sexual nuclei—**has been disturbed** in some manner. The injurious substance may be a body-product, or it may come from without, and at the same time also produce its harmful effects upon the body. Consequently, in these cases we may speak of the *acquiring of a transmissible pathological characteristic through the action of an extrinsic injurious influence*. This does not mean, however, as has been accepted by many, that the tissues of the body, under the influence of extrinsic harmful influences, first suffer changes in themselves, and then transfer these changes to the germ-cells. It is to be believed, rather, that the harmful influence acts directly upon the sexual nuclei or the segmentation-nucleus, producing in these a *change of some kind*, which later leads to a pathological development of the individual developing from the impregnated egg. It is a matter of no importance, so far as the nature of the resulting pathological variation is concerned, whether the somatic tissues also suffer changes, or of what nature such changes may be.

If a transmissible pathological characteristic arises, it may, in case it does not affect life or prevent reproduction, actually be transmitted, although this does not necessarily follow. The chances that a particular characteristic will be transmitted are greatest when both parents possess the same quality, as, for example, when both parents are affected with hereditary deaf-mutism or with near-sightedness. If the characteristic is wanting in one parent, there is produced most frequently a new germ-variation, in which the pathological characteristic fails entirely to manifest itself, and in the following generations may completely disappear. If several descendants are begotten, the pathological characteristic, in case it is not wholly lost, may show itself in only a few of the descendants, and in these in either a modified or in an aggravated form. Not rarely it happens that the characteristic remains latent in one generation—that is, is confined to the sexual cells, and appears again in the second generation.

There seems to me to be no doubt that, through the copulation of two sexual nuclei possessing different hereditary tendencies, variations may be produced, and that among these there may be some which are to be regarded as pathological. It is more difficult to answer the question whether, besides these, there are not also transmissible variations of a pathological nature, which arise through influences which affect the sexual nuclei or the segmentation-nucleus; and further, if we accept the existence of such variations, with what frequency do they occur. *Weismann*, according to his most recently published statements, holds the opinion that the basis of transmissible variations is to be found, not in the amphimixis, but rather in the direct action of external influences upon the sexual nuclei. Starting from the assumption that the variable cells or cell-groups derived from the germ (by him designated as *hereditary pieces* or *determinates*) are represented in the germ-plasma by special particles, which are formed by the grouping together of a number of *life-trophoblasts* or *biophores* (molecular groups which represent the smallest units of life), and which he calls *determinants* or *determining pieces*, he believes that he is warranted in ascribing the transmissible variation primarily to the changes produced by external influences in the determinants or group of determinants contained within the nuclear chromatin, so that finally the hereditary pieces or determinates derived from them also suffer changes. He believes that such an influence might be exerted by excessive nourishment of a determinant, causing it to grow more rapidly. For example, he regards it as possible that many congenital malformations (for example, an increase in the number of fingers and toes) can be referred to a reduplication of the determinant-groups caused by increased supply of nourishment. According to *Weismann*, the amphimixis has only a secondary influence in the origin of a permanent variation, in that it mixes in constantly new manner the varia-

tions dependent upon the changes in the determinants, but does not in itself produce new variations. "The deviations which the determinants suffer through unequal conditions of nutrition constitute the material out of which, through amphimixis in connection with selection, the visible individual variations are produced, through whose increase and combination new forms arise."

I agree with Weismann in so far as the assumption that the appearance of a new variation of pathological nature is *in part* to be referred to changes in the determinants contained within the sexual nuclei, due to the direct action of extrinsic influences. I do not, however, believe that there is sufficient ground for attributing, as does Weismann, the formation of new separate parts to an over-nourishment of single groups of determinants. Such a dependence of the germ-plasma upon the surrounding nutritive material seems to me scarcely conceivable, and is opposed to all views hitherto held regarding the nutrition of cells. Not only quantitative but much rather qualitative changes of the food-material would appear to be necessary in order to produce changes in the organization of the determinants. Further, I hold that the amphimixis has not only a secondary but much more a primary significance with regard to the origin of pathological variations, in the sense that it itself is able to produce new variations. Finally, it seems to me that we cannot at the present wholly set aside the hypothesis of *Nägeli*, according to which the idioplasm is capable of altering its own condition, from within outward, in certain fixed directions and according to certain fixed laws, and thus may produce new characteristics.

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## 64 THE TRANSMISSION OF INFECTIOUS DISEASES TO THE FŒTUS.

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- See also §§ 16 and 17.

§ 19. In addition to the pathological conditions already mentioned, **hereditary transmission** appears to occur in the case of a few infectious diseases, particularly syphilis, smallpox, varicella, intermittent and recurrent fever. At all events, cases are observed in which a child, at birth or shortly after, shows symptoms of the same disease from which the father or mother had been suffering either at the time of procreation or during gestation. Such a phenomenon is, however, entirely different from that already spoken of as a hereditary transmission.

The infectious diseases are caused by organisms which multiply in the body. The transmission of the disease to the child becomes possible only when the micro-organisms causing the disease find their way into the sexual germ-cells, and then also into the impregnated egg, or else penetrate from the maternal organism into the tissues of the child during its intra-uterine development. The latter can occur as long as the child remains in the uterus, and we must therefore assume that the infecting organisms pass through the decidual membranes and the outer coverings of the ovum—in the later stages of pregnancy through the *placenta*—and so are transported from the maternal to the foetal organism. It is also possible that when cohabitation is continued after pregnancy, the micro-organisms, which may enter the vagina with the sperm, may penetrate into the uterus and thence into the impregnated egg.

The transmission of infectious diseases to the foetus is beyond all doubt a possible occurrence. In the case of syphilis this may take place at the moment of impregnation as well as later during the course of intra-uterine development, so that syphilis may be transmitted to the child by the father as well as by the mother. In the case of smallpox, endocarditis, scarlet fever, many instances of the infection of the foetus *in utero* have been observed; and from recent observations and experimental investigations there can be no doubt that anthrax-bacilli, pus-cocci, and pneumococci, and under certain conditions also typhoid-bacilli and tubercle-bacilli can pass through the placenta to the foetus. This can only occasionally occur, when the bacteria gain entrance to the

blood-channels of the placenta and are able to multiply there and to penetrate into the fœtal vessels, an event which is rendered possible chiefly by the damage done to the placental tissue by the multiplying bacteria, whereby the latter are able to pass through and also to multiply within the tissues of the placenta.

There are, therefore, both **germinative** and **conceptional**, also **post-conceptional**, **intra-uterine infections**, which constitute a **pseudo-form of inheritance**, in which the peculiar characteristics of the individual are not transferred to the embryo, but instead an organized poison finds its way into the germ or into the already developing fœtus, where it increases and produces the same disease as that affecting the parent.

Only of the transmission of disease from the mother to the fœtus *in utero* do we possess a more exact knowledge. Germinative, paternal, and maternal transmission is known to occur only in syphilis, the specific poison of which is not yet known to us. If syphilis is due, as is supposed, to a schizomycete, the specific organism, in cases of germinative infection, must at the time of the discharge of the sexual cells have been present either in the egg or spermatozoön. In the latter case, coincidently or immediately following impregnation, the micro-organisms gain entrance into the egg, and remain there in a living state without actually hindering the further development of the ovum. It must further be assumed that the bacteria during the growth of the fœtus pass into certain tissues and here later give rise to disease-processes.

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## CHAPTER II.

### The Spread and Generalization of Disease Throughout the Organism. Autointoxications and Secondary Diseases.

#### I. Metastasis and Embolism and Their Significance in the Etiology of Lymphogenous and Hæmatogenous Diseases.

§ 20. *The transportation, through the blood or lymph-stream, of a disease-producing agent, and the production of disease at the point of deposit of such agent, is termed metastasis.* This is one of the most common modes of the spread of disease throughout the body. Ordinarily the term metastasis is applied particularly to those cases in which the transportation of a given substance is followed by easily recognizable clinical and anatomical manifestations of disease, especially those of inflammation or tumor-formation, so that we are accustomed to speak of *metastatic inflammations* and *metastatic tumors*. There is, however, no good reason for not including also under metastasis those cases of transportation of corpuscular elements through the lymph or blood stream in which the changes produced by the transportation are less striking, and are recognizable only through a more careful anatomical or microscopical investigation.

The term metastasis indicates further that the substance deposited has arisen from some other known place within the body. If the source of the transported material is not known, or at least cannot be definitely located, we are accustomed to speak of **lymphogenous and hæmatogenous deposits and diseases**. The same designation is also applied to deposits of known origin.

The **significance of metastasis** is in all cases **dependent upon the properties of the transported body**. Insoluble bland foreign bodies of small size may have little effect upon the tissue; soluble and chemically active substances may, on the other hand, produce important tissue changes. Bacteria capable of reproduction may give rise to a disease which corresponds in general to that produced at the primary focus of infection. Tumor-cells capable of growth may develop into a secondary tumor. The **size of the transported body** is of essential importance in hæmatogenous metastasis, in that small bodies may pass all the blood-vessels, even the capillaries, while larger ones will be carried only through those vessels whose lumen is sufficiently large to admit them. When the latter have by any means obtained entrance to the arteries of the greater or lesser circulation and are carried along by the blood-stream, they will become lodged at those divisions of the vessels where the vessel-lumen is too small to admit them, and will thereby more or less completely obstruct the vessel. This occurrence is designated by the special term **embolism**; the body blocking the vessel is called an **embolus** or a **vessel-plug** (Fig. 2, *b, c*). The effect of embolism is in general the more or less complete obstruction of the vessel, partly through

the embolus itself, partly through an associated coagulation of the blood. As a result of such obstruction there is an interference with the circulation, which may vary greatly in different cases, in that behind the point of obstruction there may be established either a complete or partial compensatory circulation, or in other cases such a compensation may be entirely wanting. When the compensation is incomplete or wholly absent, the area of tissue supplied by the obstructed vessel undergoes degeneration or dies.

Both lymphogenous and hæmatogenous metastasis usually occur in the direction of the normal current, but under special conditions a transportation in the opposite direction may take place—**retrograde metastasis**. Such a change of current in the lymph-vessels occurs when the normal escape of lymph from the region involved is hindered through stoppage of the lymphatics, and the lymph is forced to seek other outlets. A similar condition may occur in circumscribed areas of the peripheral blood-vessels. In this way clots arising in the right heart or in the large veins of the body may be transported into the peripheral veins; particularly under conditions in which there occur backward waves of blood which gradually force the clots back into the smaller veins. According to the experimental investigations of Arnold upon dogs, foreign bodies (wheaten grits), which were too large to pass the capillaries, when introduced into the jugular or crural veins, as well as into the longitudinal sinus of the dura mater, were carried by retrograde metastasis not only into the main trunks, but also into the smallest branches of the veins of the liver, kidneys, heart, extremities, dura mater, pia mater, and orbit, as well as into the posterior bronchial veins.

In the case of a defect in the septum of the heart, bodies circulating in the blood may pass directly from one side of the heart to the other, and thereby give rise to a **crossed** or **paradoxical embolism**.

§ 21. **The substances which may be transported in the process of metastasis** may be conveniently divided into six groups, this classification being based partly upon the origin, partly upon the character of the transported body, and partly upon the effects of the metastasis.

In the first group are placed insoluble lifeless substances composed of very small particles, which enter the body from without, and which may be designated collectively as **dust**. The majority of these substances enter the body in the respired air, and pass from the lungs into other tissues. A smaller part may enter the tissues directly through accidental or intentional wounds (tattoo). Most frequently these substances are particles of soot, coal- and stone-dust, more rarely metal, porcelain, tobacco, hair, or other kinds of dust. In tattooing of the skin, soot, cinabar, and other granular pigments are used.

The behavior of the tissues of the body toward such substances will be treated of elsewhere; it is only necessary to mention here that these forms of dust, sometimes in a free state, sometimes enclosed within cells, are deposited first in the tissues nearest the point of entrance, further in the lymph-vessels and lymphatic glands. In the latter location they

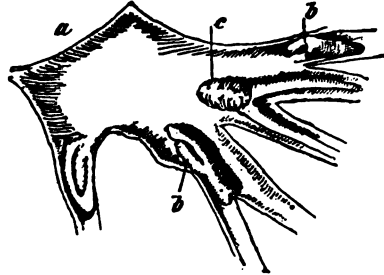


FIG. 2.—Multiple emboli in the branches of the pulmonary artery, after thrombosis of the right auricle. *a*, Arterial branch; *b*, embolus; *c*, embolus with secondary thrombosis.



may remain for a life-time; but in cases of excessive deposit they may be carried beyond the lymph-glands, especially in those instances in which the glands, because of the great deposit, undergo softening and give rise to inflammation and proliferation of the tissues in their neighborhood. Very often as a result of such changes the affected glands become confluent with and break into neighboring veins. This event is especially likely to happen at the hilum of the lungs, whereby the contents of the gland ultimately, sometimes slowly, at other times more rapidly, gain entrance to the vessel-lumen and are carried away by the blood-stream. In the case of the lungs, dust may be deposited directly in the vessel-walls and gradually penetrate as far as the intima. Further, the particles from a broken-down lymph-gland can again enter the lymph-stream, and, if not again arrested by some lymphatic gland, may reach

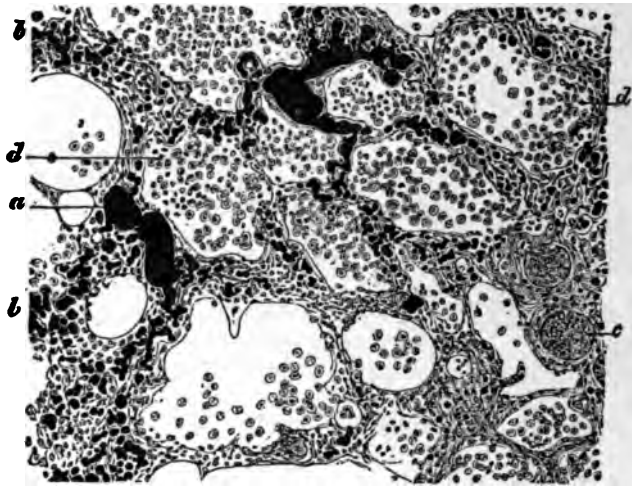


FIG. 3—Fat-embolism of the lungs (Flemming's solution, safranin). *a*, Arteries filled with blackened masses of fat; *b*, fat-droplets in capillaries; *c*, veins; *d*, cells in the alveoli.  $\times 100$ .

the blood-stream. It is also conceivable that softened lymph-glands may break directly into the thoracic duct.

As numerous experiments have shown, the dust gaining entrance to a blood-vessel remains but a very short time in the circulation. Large amounts artificially introduced into a vein disappear in a few hours from the circulating blood. The greater part collects in the capillaries of the liver, spleen, and bone-marrow, partly free and partly within leucocytes, in the former case adhering to the surface of the endothelium. After a short time the leucocytes containing the dust particles wander out from the vessels, so that the dust collects more and more in the tissues, where it is held for a long time, partly in wandering-cells, partly in fixed cells, and partly free, and under certain conditions may remain here during the lifetime of the individual. In the mean time a part is carried in the lymphatics to other regions and there deposited, particularly in the portal and celiac lymph-glands. According to the researches of Kunkel and Siebel, still other cells containing dust-particles may reach the surface of the body-cavities, either through the capillaries of the lungs, the parenchyma of the tonsils, and probably also from the lymphoid tissue of the

intestines, and in this way be discharged externally. From the liver the dust-particles may be passed out in the bile. According to observations which may be not infrequently made on inflamed organs, wandering leucocytes are able to take up a great number of the particles lying in the tissues and transport them from the lungs, intestinal tract, and other organs to the surface, and in this way clear the tissues.

The second group is composed of portions of the body itself, which occasionally may be transported through the blood-stream; namely, **tissue-detritus, parenchymatous cells, and dead, coagulated, and broken-up constituents of the blood.** Of the elements arising from the destruction of tissue, **fat-droplets** (Fig. 3, *a, b*, and Fig. 4, *a, b*) most often find their way into the circulation; particularly when through trauma or some other pathological process, as, for example, hæmorrhage, the tissues are destroyed. This occurs most frequently in cases of crushing, destruction, and violent agitation of fat-tissue, as may happen in the case of the different panniculi adiposi and the bone-marrow; but fat may also enter the circulating blood through destruction of liver-tissue. The parenchymatous cells most frequently entering the circulation are *liver-cells* (Turner, Jürgens, Klebs, Zenker, von Recklinghausen, Schmorl, Lubarsch), *placenta-cells* (Schmorl, Lubarsch, Leusden), and *bone-marrow cells* (Lubarsch). Ordinarily these are carried into the pulmonary arteries and capillaries, but through retrograde metastasis they may be carried into the veins, and through paradoxical embolism into the arteries and capillaries of the systemic circulation. Embolism of liver-cells and bone-marrow giant-cells is caused by traumatic and toxic injuries and hæmorrhages of the affected tissues. Placental-cell emboli, in the form of multinuclear giant-cells, have been observed especially in puerperal eclampsia, but occur also in the course of normal pregnancies (Leusden). In diseased conditions of the intima of the heart or blood-vessels, *degenerated endothelium, broken-down and degenerated masses of connective tissue of the intima, portions of the valves, and material of similar nature* may gain entrance to the blood-stream. *Fragments and disintegrated portions of blood-corpuscles* may enter the circulation from hæmorrhagic foci or may arise within the vessels themselves, in the case of degenerative changes produced in the blood through the influence of various harmful agents. Coagulated masses of blood enter the circulation when a **thrombus**—i.e., blood coagulated in the vessels (see Chapter IV.)—breaks loose, either *in toto* or in fragments.

The fate of the last-named substances is for the chief part dependent upon their size and physical properties. All fragments of much greater diameter than the lumen of the capillaries become lodged in the bifurcations of the arteries (Fig. 2, *a, b*) and usually occlude the same. This occurs most frequently in the case of dislodged thrombi or of fragments of such; on the other hand, fat-droplets usually pass into the capillaries, where part remain, while others pass through and later become lodged in some other place. Since the fat occasionally passes first into the veins

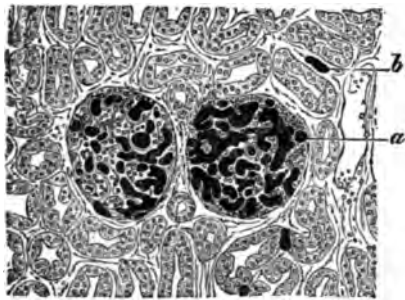


FIG. 4.—Fat-embolism of the kidney (Flemming's solution, safranin). *a*, Glomeruli with fat in the capillaries; *b*, fat-droplets in the intertubular capillaries.  $\times 100$ .

The fate of the last-named substances is for the chief part dependent upon their size and physical properties. All fragments of much greater diameter than the lumen of the capillaries become lodged in the bifurcations of the arteries (Fig. 2, *a, b*) and usually occlude the same. This occurs most frequently in the case of dislodged thrombi or of fragments of such; on the other hand, fat-droplets usually pass into the capillaries, where part remain, while others pass through and later become lodged in some other place. Since the fat occasionally passes first into the veins

of the body and thence to the heart, the fat-droplets collect especially in the capillaries of the lungs (Fig. 3, *b*); but they may also pass through the lungs into the capillaries of the greater circulation, and are then found especially in the intertubular and glomerular capillaries of the kidneys (Fig. 4, *a, b*), and also to some extent in the capillaries of the brain. Capillary fat-embolism causes a noticeable disturbance of the circulation only when of extensive occurrence; in this case it may lead to the production of oedema. Furthermore, the fat disappears in the progress of metabolism.

Parenchymatous cells (in so far as the entrance into the circulation of small living cells of the character of lymphoid cells is not concerned) become lodged in the capillaries or smaller arteries in the case of arterial metastasis. The latter is especially true of liver-cells when entering the circulation *en masse*. At the place of lodgment the presence of parenchymatous cells may lead to a heaping-up of blood-plates and a hyaline coagulation; this is particularly true of liver-cell emboli. The cells themselves do not multiply, but they may remain preserved for a certain length of time; according to Lubarsch, as long as three weeks. They then gradually die, the protoplasm dissolves, the nuclei swell or shrink, and finally lose their chromatin. In the case of multinuclear cells the dissolution is preceded by a clumping of the nuclei.

The point of lodgment of loosened thrombi or fragments of thrombi depends upon the path which they take, as well as upon their size. Since thrombi may be formed in the systemic veins, right heart, and pulmonary arteries, as well as in the pulmonary veins, left heart, and systemic arteries (see Chapter IV.), it is possible for embolism to occur in any of the arteries of the greater or lesser circulation. Very often the emboli lodge at the bifurcation of arteries, forming the so-called **riding or straddling emboli** (Fig. 2, *c*). Through retrograde metastasis emboli may be carried from the venæ cavæ or larger veins into the smaller veins. Defects in the septum of the heart may lead to the production of a paradoxical embolism.

Small fragments of thrombi, dead red blood-cells or fragments of such, endothelial cells undergoing disintegration or fatty degeneration, etc., meet the same fate as dust-particles. They may remain free or be taken up by cells; they are soon removed from the circulation and collect especially in the spleen, liver, and bone-marrow, where they undergo further changes and are destroyed. The products resulting from the destruction of red blood-cells may persist for a long time in the organs named, as colored or colorless deposits.

The third group of substances producing metastases is composed of **living cells**, which, originating from **proliferating tissue-foci** and having gained entrance to the circulation through direct rupture into the blood-vessels, or having entered the lymphatics, are carried to other organs. This process may be observed in the case of **tumors** growing by infiltration. The metastasis of living cells from such a tumor leads through the proliferation of the transported tumor-cells to the production of **metastatic daughter-tumors**, which in the case of lymphogenous metastasis develop first in the lymph-vessels and lymph-glands, but in the case of direct rupture into the blood-vessels arise in that part of the vascular system to which the tumor-cells are carried by the blood. The metastasis usually occurs in the normal direction of the blood- and lymph-streams, but *retrograde transportation* may also occur, whereby a tumor which has broken into one of the systemic veins may give rise to metas-

tases in the region drained by smaller branches of other systemic veins. Retrograde metastasis is not infrequently observed in the lymphatic system, when closure of the efferent lymph-channels has produced a change in the direction of the lymph-current.

In the fourth group may be placed all those processes characterized by the entrance of **vegetable** or **animal parasites** into the circulation. If under such circumstances these organisms do not find conditions suitable for their development, they are quickly eliminated from the bloodstream and destroyed under the influence of metabolic processes. But if they are able to reproduce themselves anywhere, they will give rise to the production of **metastatic foci of infection**, which are located partly in the vascular system, but also partly extending thence into the neighboring tissues. The secondary foci in the case of bacterial invasion have in general the same character as that of the primary. If an embolus contains organisms capable of producing tissue-necrosis, inflammation, and putrid decomposition, there will occur, along with the embolism and the accompanying disturbances of circulation, suppuration and sloughing—that is, there will be a repetition of the same processes occurring at the original seat of infection.

As the fifth group of metastatic processes may be classed together those cases in which **constituents of the human body having undergone solution** are transported in the soluble state and again **deposited in a solid form**; and also those in which **extrinsic substances are taken up by the body in a soluble form** and are then **deposited in the tissues in a solid state**. Of the first class there occurs most frequently the resorption of bile-pigments into the circulation within the liver, so that these may permeate through the most varied tissues, and at the same time give rise to granular or crystalline deposits of *bile-pigment*. Not infrequently *soluble derivatives arising from the destruction of red blood-cells in the circulation* are deposited in the form of droplets, granules, and crystals in the spleen, bone-marrow, liver, and kidneys. Further, *soluble derivatives of hæmoglobin* may be taken up by the lymph and blood from *hæmorrhagic foci*, and deposited in different organs.

When preparations of silver are, for medicinal purposes, introduced into the body through the gastro-intestinal tract for long periods of time, there may occur a deposit of *fine granules of silver* in the connective tissue of the skin, in the glomeruli, medullary pyramids of the kidneys, intima of the large arteries, adventitia of the small arteries, in the neighborhood of mucous glands, connective tissue of the intestinal villi, in the choroid plexus of the cerebral ventricles, and in the serous membranes. Tissues showing such a deposit have a grayish-brown color.

The fact that the epithelial tissues and the brain are not affected shows that there is a selective action on the part of the tissues, and that this selective action differs essentially from that which is seen in the case of a metastatic deposit of corpuscular elements. It may therefore be assumed that the chemico-physical character and the functional activity of the tissues coming into contact with substances in solution exert a determining influence upon the separation and precipitation of such substances.

As a sixth group of metastatic processes may be classed the entrance of **air into the circulation**. If in any manner a large amount of **air gains entrance to the right heart**, an event which occurs especially in case of injury to the large veins lying in the neighborhood of the thoracic cavity, or more rarely from the opening of a vein, for example,

of a stomach-vein, through ulcerative processes, the air mingling with the blood forms a foamy mass, which the contractions of the heart are scarcely able to drive onward. As a result the left heart receives little or no blood, the aortic pressure falls, and the affected individual quickly dies. Should the air enter the circulation in small amounts or intermittently, it may be carried by the blood-stream in form of air-bubbles and circulate through the entire body. Larger amounts may lodge for a time in the vessels of the major or minor circulation, obstruct their lumen, and cause disturbances of the circulation, which may give rise to functional disturbances of the brain and respiration. If these conditions do not cause death, the air is after a time resorbed.

If the lung-tissue be ruptured through trauma or through violent coughing, screaming, or vomiting, etc., **air may be forced into the connective-tissue spaces and lymphatics**, and may extend through these into all parts of the lungs, pleuræ, and the mediastinum, as well as into the skin. The conditions thus produced are termed *emphysema* of the skin, of the subcutaneous tissue, of the mediastinum, etc. Under certain circumstances the air may spread through a large area of the subcutaneous lymph-vessels and connective-tissue spaces, whereby the skin presents a blown-up appearance and when pressed upon produces a crackling sound.

*Arnold*, supported by numerous investigations, believes that the lymph-glands form a perfect filter for the dust carried to them, and that therefore metastasis of dust is possible only through the rupture of a lymph-gland into the blood-stream. In so far as the glands do not show too great structural changes, his view appears to me correct; but in those cases in which the lymph-glands undergo softening, as a result of being overloaded with dust, portions of necrotic tissue containing dust may pass from the glands into the efferent lymphatics.

As will be shown later (see Inflammation), it is an invariable fact that wherever foreign bodies or dead tissue-masses lie in a living tissue, wandering-cells are sure to appear; and these, in so far as it is possible, take up into their substance more or less of the corpuscular material present. This material is then carried further, especially to the lymph-vessels and lymph-glands. It is very probable that a portion of this material—in so far as it may be so utilized—serves as nourishment for proliferating tissue-cells.

According to *Siebel* and *Kunkel*, granules of cinnabar and indigo injected into the blood-stream of a frog are quickly taken up by leucocytes, and after one to two hours no more free granules are to be found in the circulating blood. After twenty-four hours the leucocytes containing pigment-granules have disappeared from the circulation, and lie for the greater part clumped together in the capillaries, the greatest numbers being found in the capillaries of the spleen, liver, bone-marrow, and the lungs, while they occur in smaller numbers in the capillaries of the kidneys, and in still smaller numbers in the capillaries of the heart-muscle.

Even after two hours free pigment and cells containing granules are found outside of the vessels, and after a few days they have almost wholly disappeared from the vessels. The granules lie then partly in wandering-cells, partly in fixed cells, as well as in the free cells of the splenic pulp (*Ponfick*) and bone-marrow. They may be found in these organs for weeks afterward (*Hoffmann*, *Langerhans*). In both frogs and dogs some of the granule-containing cells find their way into the lumen of the alveoli and bronchioles and so pass out of the body. In the liver the pigment-particles for the greater part adhere for a short time to the endothelium of the liver-capillaries; another part is found in leucocytes, which later wander out from the vessels into the tissues. Thence they are for the greater part taken up into the lymphatics of the liver and ultimately reach the lymph-glands. A part of the granules finally pass out with the bile, but by what course they reach the bile-vessels is not known. In dogs the pigment-granules also collect in the tonsils and are carried to the surface through the epithelium by the leucocytes which have taken them up.

According to the investigations of *von Kupffer*, the endothelium of the liver-capillaries (formerly designated as the stellate-cells of Kupffer) possesses phagocytic properties, and takes up small particles circulating in the blood-stream.

According to the observations of *Jadassohn* ("Pigmentverschleppung aus der

Haut," *Arch. f. Derm.*, 24 Bd., 1892) and *Schmorl* ("Pigmentverschleppung aus der Haut," *Centralbl. f. allg. Path.*, 4 Bd., 1893), both normal and pathological pigment may be transported from the skin to the lymph-glands—in other words, a *pigment-metastasis* may take place.

According to *Lewin* (*Arch. f. exp. Path.*, 40 Bd., 1897), if the outflow of urine from the bladder be hindered, small foreign bodies can pass into the kidney-pelves, and thence into the urinary tubules, lymph-vessels, and veins, and into the general circulation.

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## II. Secondary Local and General Diseases. Autointoxication. Diseases Caused through Disturbances or Cessation of Gland-Functions.

§ 22. If through the action of any injurious agent a local tissue-change is produced, there occurs first a **primary local disease** or **organ-disease**, which is accompanied by a disturbance of function of the affected part. If the injurious agent passes into the body-juices and into the blood without causing noticeable changes at the point of entrance, while within the body it gives rise to local changes, the resulting condition may be designated as a solitary or multiple **lymphogenous** or **hæmatogenous local disease** or **organ-disease**.

Local diseases may during their entire course remain confined to the organ originally affected, yet very frequently they lead to further **secondary diseases of organs** or to a **general disease**.

The *first method by which disease-processes spread* through the body is through *metastasis*, already described (§§ 20 and 21), by means of which there are very frequently formed, not only solitary, but innumerable foci of disease throughout the body. Not infrequently there may occur such a *generalization of disease* by way of the blood and lymph-channels (tuberculosis, suppurations, and carcinomatous growths), that the majority of the organs will be found to be affected and show correspondingly more or less easily recognized functional disturbances.

A *second method* of the spread of disease occurs in those diseases in which in the primary foci there are formed toxic products which, taken up into the lymph and blood, produce such changes in different organs that they must be regarded as *intoxications by poisonous substances arising from diseased foci*. This intoxication is, as shown in § 12, of very common occurrence in the *infectious diseases*, and leads not only to *secondary degenerations of organs*, but much more to the picture of a more or less severe *general disease*, as shown by general disturbances of metabolism, fever, and disturbances of the central nervous system.

A *third form* of the spread of disease-processes throughout the body becomes possible by reason of the fact that the integrity and normal functional capacity of many organs are to a great measure dependent upon the function of other organs; and, further, upon the fact that the organism needs, for the preservation of its normal condition, the perfect functional working of its organs, and in the case of many organs cannot permanently dispense with their functions. There is, therefore, a large group of *local and general diseases which arise as the result of the imperfect functional activity of this or that organ*.

A *fourth mode* of origin of secondary diseases is through *autointoxication*—that is, through a *poisoning of the organism by substances which arise in the body itself through its own activity (metabolic poisons)*. The *place of origin* of these substances is in part the intestinal tract (*enterogenous poisons*), and partly the tissues (*histogenous poisons*). The cause of the poisonous action of these products of metabolism lies partly in the fact that they are produced in an increased amount or are retained within the body as a result of disease of certain glands; partly also that they are not transformed to non-poisonous bodies, as is the case under normal conditions. In conditions of disturbed metabolism poisons foreign to the normal body may be produced.

*Disturbance of the function of different glands may cause, in addition to autointoxication, other manifestations of disease.*



§ 23. **Secondary diseases which arise as the results of pathological conditions of individual organs** occur with great frequency as the result of *pathological changes in the blood and circulatory apparatus*.

The circulatory apparatus and the blood therein contained bear certain relations to all the body-tissues, and accordingly *diminution in amount and pathological alterations of the blood, as well as changes of the blood-vessels*, often give rise to diseased conditions of this or that tissue or of the entire organism. If the hæmoglobin-content of the blood is decreased through a diminution in number of the red blood-cells (oligocythæmia), or through a pathological condition of the same, or if the hæmoglobin through the action of carbon monoxide is rendered incapable of taking up the oxygen of the air, the body-tissues will no longer receive a normal amount of oxygen; consequently there will arise, in case the amount of oxygenation falls below a certain point, disturbances of nutrition, as the results of which there occur very frequently conditions of fatty degeneration, and under certain circumstances death through paralysis of the nervous centres.

Should an artery become narrowed or closed through thrombosis or embolism, or thickenings of its walls, as in the case of the arterial disease known as *arteriosclerosis*, there will arise in the region supplied by the affected vessel a local deficiency of food-supply and oxygen, *local asphyxia*, and later *degenerative processes*, which frequently end in the death of the specific parenchymatous elements, at times also of the connective-tissue framework.

In the brain and spinal cord the vessel-changes lead to ischæmic processes of softening, which frequently result in paralysis, and not rarely in death. In the heart there results a diffuse fatty degeneration or local softening of the heart-muscle, giving rise to disturbances of cardiac activity or often even to complete insufficiency. In the kidneys the secreting glandular parenchyma, together with a portion of the connective tissue, undergoes necrosis or atrophy; and the loss of these substances gives rise to local or widespread contractions, which, according to their origin, are designated as embolic or arteriosclerotic atrophies.

In the stomach ischæmia of the mucous membranes gives rise to local ulcerations; in the liver and muscles to atrophic conditions. No tissue can withstand the harmful effects of a long-continued anæmia, and consequently the narrowing and closure of arteries, through the formation of clots or through changes in the vessel-walls, play a very important rôle in pathology; and are not only the causes of *anæmic necrosis* (see Chapter V.) and *hæmorrhagic infarction* (see Chapter IV.), but also of numerous *progressive atrophies of organs*. In the pathogenesis of the last named, arteriosclerosis has an especially important part, since in old age it is of very common occurrence, and gives rise to tissue-degenerations in organs of the most different structure. As evidences of such degenerative processes, the majority of the affected organs show later areas of scar-tissue, in which the specific parenchyma has disappeared while the connective tissue has increased.

The active participation of the vascular apparatus in all *inflammatory processes* (see Chapter VII.), the *disturbance of circulation* through the alteration of the vessel-walls, the *shifting and changes of the vascular channels* which result from the closure of old vessels by proliferation of endothelium or through thrombosis, as well as from the formation of new vessels, make easily comprehensible the fact that in all chronic inflammations the specific cells dependent upon a regulated nutrition undergo

degeneration and are frequently replaced by connective tissue of a lower grade than normal.

A profuse watery discharge from the *intestines* may deprive the organism of water. If, as a result of stenosis of the œsophagus or pylorus, a sufficient amount of food is prevented from entering the intestinal tract, or if the stomach and intestine are no longer able to digest the food brought to them and to prepare it for assimilation into the body-juices, the organism as a whole becomes poorer in albumin and fat.

If the *heart* is no longer able to force onward with normal strength the blood coming to it, there will arise in various organs changes due to venous stasis. If the *respiration* is hindered or imperfect, the composition of the blood suffers changes. Collection of fluid in the thoracic cavity causes compression of the lungs; interference with expiration, with free inspiration, leads first to distention of the lung and later to atrophy. If a part of the *lung* has been rendered useless by chronic inflammation, the inspiratory enlargement of the thorax affects only that portion of the lung which is capable of functioning, and this part becomes over-distended and in consequence finally atrophic.

Through enlargement of the *liver* the neighboring organs are compressed; diseases of the parenchyma of the liver give rise to disturbances of the circulation of blood through the organ, and stasis throughout the portal circulation with resulting ascites.

Hindrance to the outflow of *urine* from the ureters renders difficult the secretion of the kidneys and leads to their atrophy. The loss of a *large portion of the parenchyma* is followed by increased blood-pressure in the aorta, increased action of the heart, and hypertrophy of that organ.

An *increased resistance in the pulmonary circulation* due to diseased conditions of the lungs is often followed by dilatation and hypertrophy of the right heart. *Obstruction to the flow of blood through the aortic opening* leads to hypertrophy of the left ventricle. Stenosis and insufficiency of the mitral valve cause a stasis of blood backward through the lungs to the right heart. This may be compensated for through hypertrophy of the right ventricle, or may extend farther back into the veins of the systemic circulation.

An *oblique position of the pelvis* leads to curvature of the spine. *Stiffness* and *immobility* of a joint cause atrophy of the muscles moving the joint, the atrophy being due to inactivity.

*Diseases of the nervous system* may give rise to functional disturbances and anatomical changes in any organ of the body—in glands, muscles, skin, bones, lung, heart, intestine, etc. These changes are to be referred partly to stimulation, partly to inhibition or arrest of nervous impulses, and partly to anæsthesia (anæsthetic tissues being especially liable to injury). Destruction of the large ganglion-cells in the anterior horns of the spinal cord leads to the atrophy of the corresponding peripheral nerves and muscles. Paralyzed extremities become atrophic. Diseased conditions in the region of the respiratory and vasomotor centres lead to disturbances of respiration and circulation. After injury to certain portions of the medulla oblongata, after concussion of the brain and spinal cord, through the presence of tumors in the brain, after psychical affections, after poisoning of the nervous system, there is caused under certain conditions a rapid withdrawal of the glycogen of the liver into the bloodstream and the excretion of sugar in the urine. Stimulation of peripheral nerves may produce abnormal reflex sensations and movements as well as circulatory disturbances in other parts of the body. Paralysis

of both vagi or of their branches, the recurrent laryngeal nerves, through inflammatory changes or through pressure from neighboring lymph-glands, etc., may be followed by inflammation of the lungs, in that the accompanying paralysis of the laryngeal muscles favors the entrance of foreign bodies into the lungs during inspiration.

The so-called **trophoneurotic diseases of the tissues** are not mentioned above, for the reason that the trophic relations of the nervous system to the individual tissues are not yet clear, and the views of different authors as to the dependence of the tissues upon the nervous system vary greatly. Many authors ascribe to the trophic action of the nervous system a far-reaching influence upon the conditions of the tissues, and seek the nerves forming the connections with the nerve-centres, partly in the motor, secretory, sensory, and reflex nerves, as well as in special trophic nerves. Thus, for example, muscular atrophy, glandular atrophy, atrophy of the bones and joints (in tabes and syringomyelia), different pathological conditions of the skin characterized by thinning, exfoliation of the epithelium, loss of hair, inflammations, etc., unilateral tissue-atrophies, necroses, also hypertrophic proliferations of muscles, glands, skin, or bones, etc., are all referred to affections of the nerves.

It cannot be doubted that both degenerative and hypertrophic tissue-changes and inflammations often occur as sequelæ to disturbances of innervation, but these most probably are not the direct result of the removal or change of nerve-influences affecting the tissues, but are rather the results of increased or decreased functional activity of the tissue, or of injuries, inflammations, or disturbances of circulation, which have developed in connection with the disturbances of innervation—for example, in connection with the loss of sensibility: *Golz and Ewald*, after completely destroying the thoracic and lumbar portions of the spinal cord of dogs, were able through great care to preserve the skin of the animals thus operated upon; they are, therefore, opposed to the theory of the existence of trophic centres and nerves.

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§ 24. **Autointoxications or self-poisonings** may take place in a variety of ways. In the first place, *poisonous products of metabolism* of

normal character and produced in normal amounts *may fail of proper excretion*, and, being carried over into the juices of the body, may be retained in the same. Secondly, the *physiological production of poisonous substances may be pathologically increased*. Thirdly, it may happen that *poisonous products of metabolism*, which normally are decomposed and thereby rendered harmless, may, as a result of a local or general metabolic disturbance, *escape such destruction*. Finally, it may also happen that, as the result of pathological changes or cessation of the functional activity of certain organs, *poisonous substances may appear in the blood and also in the urine*. According to the place of origin poisons may be classed as **enterogenous**, arising in the intestine, and **histogenous**, arising in the tissues.

If **injurious products arising from the decomposition of albumin are retained or formed in excessive amounts in the intestinal canal**, they may give rise to both **local changes** and a **general intoxication**. For example, through the action of the bacteria present in the intestines, the *sulphuretted hydrogen*, arising from the sulphur of albuminous bodies, may be formed in such amount as to pass into the blood and impart its characteristic odor to the breath, and to be found also in the urine. Further, those *toxins* especially which arise from the decomposition of albumin through the action of the intestinal bacteria, when taken up into the blood are able to produce symptoms of poisoning, vomiting, headache, vertigo, stupor, acceleration and weakening of cardiac activity, etc. This action of toxins is especially marked in those cases in which the stomach or pancreas produces little or no enzyme, it being known that the enzymes have a neutralizing action upon certain toxins (see § 29). It is also probable that the tetany occurring rarely in dilatation of the stomach may be due to an autointoxication.

If the *function of the kidneys is disturbed to such a degree that the substances convertible into urea are excreted in insufficient quantity*, symptoms of intoxication may manifest themselves as the result of the retention of these substances. These symptoms are characterized by a condition of coma interrupted by convulsions and by disturbances of respiration—the symptoms collectively being designated as **uræmia**. According to von Limbeck, the retained substances have a narcotic action, the first effects of the narcosis being a dulling of sensibility and insomnia. According to Fleischer, the poison leads, through stimulation of the vasomotor centre, to a vascular spasm, as a result of which the brain becomes very anæmic. It has not yet been determined whether the toxic effects are due to a single element or to a mixture of substances. According to the investigations of Bohne, it is very probable that the retention of chlorides in the organism play the most important part in the production of this condition.

It is very probable that the condition *eclampsia*, which is associated with convulsions, is also to be regarded as a result of changes in the kidneys through which products of metabolism are retained within the organism.

Since many substances are excreted by way of the intestines, it is possible that under certain conditions a *disturbed function of the intestines* may render it difficult for the organism to rid itself of poisons and in this way lead to an autointoxication. Likewise, an *excessive accumulation of carbonic acid* within the blood, through some interference with the exchange of gases in the lungs, may cause symptoms of poisoning.

When the *excretion of bile from the liver is hindered or arrested*, through

some pathological condition in the bile-passages or in the liver itself, the elements of the bile are taken up into the blood, and the condition known as **cholæmia** is produced. Both the biliary salts and bile-pigment enter the blood, and their presence in the circulation gives rise to general lassitude, depression, mental exhaustion, inclination to sleep, slowing of the pulse-rate, itching of the skin, and abnormal sensations of hearing and taste. The effects upon the heart, muscles, and central nervous system are ascribed to the bile-salts. These also possess a hæmolytic action upon the red blood-cells. According to Bickel, ammoniac-salts, leucin, and phenol must also be taken into consideration in the explanation of the symptoms.

If the **liver** has undergone marked pathological changes, not only does the production of the bile as well as that of sugar and urea suffer, but certain substances brought to the liver from the intestines and normally decomposed by this organ may pass through it unchanged. Many believe that at least the severe symptoms (conditions of mental excitement, delirium, lethargy, coma, and cerebral paralysis) which occur in degenerations of the liver (*icterus gravis*) are to be referred in part to the presence of such substances in the blood, and base their belief upon the fact that under such conditions abnormal substances (ammonium carbonate) appear in the urine. In degenerations of the **pancreas**, large amounts of dextrose, acetone, and aceto-acetic acid (see § 25) may appear in the blood and urine. The two last-named substances have a toxic action, and many are disposed to ascribe such symptoms to a disturbance of pancreatic function. Finally, after degeneration of the **thyroid** or **adrenals** (§§ 26 and 27), pathological symptoms arise which possibly may be explained in part by the assumption that, as the result of the degeneration of these organs, poisonous products of metabolism are no longer destroyed.

In the constitutional disease known as **gout**, local deposits of metabolic products, in the form of urates, give rise to local tissue-degenerations and inflammations.

The term **autointoxication** is not used with the same significance by all writers, many of them giving to it a broader meaning than the one given above, and even applying the term autointoxication to certain intoxications caused by pathogenic bacteria. In justification of such a view it may be said that the poisons in such cases arise for the greater part from component elements of the body. At the same time such a widening of the significance of the term appears to me inexpedient, in that the cause of the decomposition lies not in the body itself, but comes from without, so that the intoxication is the result of a preceding infection. It seems to me, therefore, to be more correct to apply the term autointoxication only to those forms of poisoning which are produced by products of metabolism, either under the influence of the activity of the body-cells or through the activity of bacteria constantly present in the intestine. As authorization for including the poisoning by products arising from intestinal decomposition among the autointoxications, I draw upon the fact that the intestinal bacilli which cause this decomposition are constant inhabitants of the intestine, and, according to the investigations of *Schottelius*, are indispensable factors in the processes of nutrition of man and the higher vertebrates. The *enterogenous autointoxications*, which are caused by these intestinal bacteria and which occur especially in childhood through retention of the intestinal contents (ileus) or in acute digestive disturbances (*asthma dyspepticum*), are in their severe forms characterized chiefly by disturbance of heart-action, small and frequent pulse, cyanosis, coldness of the extremities, sunken expression, and lowering of the body temperature. They may owe their origin in part to retention of intestinal contents in this or that portion of the intestinal tract, and in part to changes in the products of decomposition (toxins and toxalbumins) depending either upon the especial character of the material taken into the intestines, or upon a change in the virulence of the bacteria, or upon a deficient production of enzymes. It is not always possible in such cases to decide whether other bacteria, foreign to the intestine, are not

also concerned in the production of poisons. The appearance of cystin in the urine is to be regarded, according to the researches of *Baumann* and *von Udranski*, as evidence of especial processes of intestinal decomposition resulting in the production of diamins.

According to the view of *Bouchard*, autointoxications are caused in particular by leucomains—that is, by the earlier products of retrogressive metamorphosis of albuminous bodies, which normally are further decomposed in the process of intra-organic oxidation until they reach the form of urea and are then excreted.

Chronic diseases whose chief characteristic appears to lie in a changed condition of the entire organism are often grouped together as **constitutional diseases**. Into this category *Samuel* places the permanent anomalies of the blood, lymph-glands, nervous tissues (neuropathic predisposition), rachitis, osteomalacia, multiple exostoses, feeble muscular development, relaxed articular ligaments, etc. *Hoffman* ("Lehrbuch der Constitutionskrankheiten," Stuttgart, 1894) collects under this term the different forms of anemia, hæmorrhagic diathesis, hæmoglobinæmia, rachitis, osteomalacia, chronic rheumatism, progressive myositis ossificans, multiple exostoses, lipomatosis, gout, diabetes mellitus, diabetes insipidus, and Addison's disease. *Nothnagel*, in his "Handbook of Special Pathology," omits the diseases of the blood from this class, and includes among the constitutional diseases only rachitis, osteomalacia, gout, obesity, chronic rheumatism, arthritis deformans, diabetes mellitus, and diabetes insipidus. From these examples it is clearly evident that the designation constitutional disease is applied to very different conditions. As a matter of fact, the diseases enumerated are not characterized by constitutional anomalies; they represent rather the sequelæ of anomalies or diseases of certain tissues, so that the use of the term "constitutional disease" finds for the greater part no true application. At the most, the designation can still be applied with fitness to obesity and gout.

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§ 25. If a gland produces an **internal secretion**—that is, if it gives to the lymph or the blood certain substances which are necessary for the normal performance of the functions of other organs or of the organism as a whole—an **alteration** or **total failure of this function** will cause more or less important disturbances of nutrition, as well as of the functional activity of other organs and of the entire organism. Such an internal secretion is ascribed to the liver, pancreas, thyroid, adrenals, thymus, and the sexual glands, yet our knowledge of the nature of these secretions is very slight and hypothetical. We are able to infer the influence exerted by these glands upon metabolism and the life of the organism only from the disturbances which arise when the glands in question become diseased. Among the most important of the diseases belonging in this category are *diabetes mellitus*, *thyrooprival cachexia*, *myxedema*, *cretinism*, *Addison's disease*, and the *functional and anatomical changes occurring in the body after castration*. In a certain sense it is proper to consider in this connection *asphyxia*, which arises from a failure of the lungs to perform properly their function, in that through the functional activity of the lungs the requisite amount of oxygen is supplied to the organism.

**Diabetes mellitus** is a disease which is characterized especially by the presence of large amounts of grape-sugar in the urine (glycosuria), accompanied by a great increase in the total amount of urine secreted (polyuria), and often also by a pathological increase of acetone and the excretion of aceto-acetic acid and  $\beta$ -oxybutyric acid in the urine. At the same time grape-sugar and these acids are found in the blood and often lead to a diminution of its alkalinity. When the acid-content of the blood is high, headache, anxiety, delirium, fainting, and finally a condition of loss of consciousness (coma diabeticum) develop, and these conditions are probably to be ascribed to an acid-intoxication (Stadelmann, Minkowski, Magnus-Levi).

The entrance of sugar into the urine may be caused by too great an ingestion of sugar, so that part passes into the urine unchanged (alimentary glycosuria). Glycosuria may also follow an injury to certain portions of the medulla oblongata (puncture of Bernard), or as the result of disease-processes in the brain (degeneration, epilepsy, mental affections, severe psychical disturbances, tumors, parasites), or of certain forms of poisoning (carbon monoxide, curare, morphine, strychnine, amyl nitrite, nitrobenzole), in which the liver probably gives up its glycogen into the blood more rapidly than normal, so that a condition of hyperglycæmia is produced.

Finally, glycosuria may be due to an inability on the part of the kidneys to hold back the small amounts of glucose found normally in the blood, a phenomenon which may be produced experimentally by the administration of phloridzin (von Mering) or of caffeine sulphate (Jacobj).

These alimentary, nervous, and toxic glycosurias are, however, to be distinguished from the ordinary form of diabetes, in that in the latter the cause of the glycosuria is to be sought, not in an increased conveyance of sugar into the blood, or in a pathological excretion of the sugar contained in the blood, but much rather in the fact that the diabetic patient is unable to decompose sufficiently the carbohydrates, and especially dextrose, while the sugars which turn polarized light to the left (levulose and inulin) ordinarily can be oxidized either wholly or at least in greater amounts than dextrose. In most cases the power to form fats from the carbohydrates is also lessened, yet there are cases in which this function is unimpaired and the sugars are stored up in the body in the form of fat (diabetogenous obesity).

According to the investigations of von Mering and Minkowski, which have been confirmed by different authors, this loss of power in the organism to oxidize the sugars brought into the body or formed normally in the body from albumin, or to store them up as glycogen or fat, is to be ascribed to an **insufficiency of pancreatic function**. This conclusion is drawn chiefly from the fact that after total extirpation of the pancreas in dogs, a diabetes of severe character, usually fatal within a few weeks, is produced, this being characterized, as is diabetes in the human subject, by polyuria, polydipsia, hyperglycæmia, glycosuria, diminution of the glycogen of the tissues, also at times by marked destruction of albumin, emaciation, excretion of large amounts of acetone, aceto-acetic acid,  $\beta$ -oxybutyric acid, and ammonia, as well as by the occurrence of a comatose condition. In support of the view that there is a definite relation between disturbances of pancreatic function and diabetes, it has been found that in certain cases of this disease in man the pancreas has exhibited demonstrable changes, of the nature of atrophy or degeneration. It should, however, be borne in mind that the anatomical investigation often fails to reveal a pathological condition of the pancreas; so that we are forced to content ourselves with the hypothesis that the anatomical changes underlying the functional disturbance of the pancreas are not demonstrable.

An exact explanation of the causal relations existing between pancreatic disease and diabetes cannot at the present time be given, yet from the foregoing experimental researches the hypothesis may be deduced that the pancreas produces an internal secretion which is of importance in the metabolism of glucose, and that if this function is lost the capacity for the decomposition of glucose is diminished. Likewise, no explanation can at present be given for the increased destruction of the albumins and the accompanying abundant production of  $\beta$ -oxybutyric acid, aceto-acetic acid, and acetone. Since these substances are not always found in experimental pancreatic diabetes, their formation probably does not stand in direct relation to the excretion of sugar, but is to be regarded rather as a complication of diabetes (Minkowski). Their occurrence in diabetes, moreover, is not always constant, and they are found in other diseases (intoxications, carcinoma, disturbances of digestion).

The occurrence of *diabetes* after total extirpation of the pancreas is evidence that this organ possesses a special function which is of the greatest importance in the normal consumption of sugar in the organism. *Lépine* is of the opinion that there is in the blood a glycolytic ferment, which is formed by the pancreas and passed from this organ into the blood; and that the cause of the mellituria in diabetic patients and in dogs from which the pancreas has been removed is to be sought in a decrease in the amount



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of this ferment. According to *Minkowski*, the experiments of *Lépine* do not offer sufficient support for this theory. At the present time it is impossible to offer a satisfactory theory of the pathogenesis of pancreatic diabetes.

If only a portion of the pancreas of a dog be removed, no diabetes occurs, or at least the excretion of sugar is much less than after total extirpation (*Minkowski*). If in dogs from which the pancreas has been totally removed a portion of pancreas is transplanted subcutaneously, diabetes does not follow (*Minkowski*, *Hédou*), but occurs if the transplanted piece be excised.

According to *Minkowski*, there is no direct communication between the secretory function of the pancreas and that function of the organ concerned in the metabolism of sugar.

Poisoning with phloridzin produces, according to *von Mering* and *Minkowski*, a marked glycosuria in most animals and in man, and the same symptoms as those seen in diabetes, may be produced by a continuous administration of the poison. Since in this case the cause of the pathological excretion of sugar lies in the kidneys and represents a flushing-out of sugar from the organism, phloridzin diabetes cannot be identified with the ordinary form of diabetes found in man—that is, with pancreatic diabetes. In dogs in which diabetes has been produced by the extirpation of the pancreas, phloridzin produces an increase in the amount of sugar excreted (*Minkowski*).

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§ 26. **Cachexia thyreopriva** is a peculiar disease caused by *deficient or totally absent function of the thyroid*, resulting either from defective development or from pathological changes in the gland. To Kocher, who observed that it followed total extirpation of the thyroid, belongs the honor of having discovered the cause of this disease. Numerous clinical observations and experimental researches which followed this discovery have confirmed the fact that the presence of thyroid tissue is essential to the maintenance of the integrity of the organism, and that the body, especially during its period of growth, requires a thyroid gland capable of functioning normally. It is probable that the gland produces a substance (thyroidine) which serves a useful purpose in the bodily metabolism. It is also possible that this gland neutralizes or destroys poisonous substances circulating in the blood.

According to experimental and clinical observations, the total extirpation of the thyroid gland produces in man and in animals, after a very short time, severe symptoms, which are characterized especially by muscular twitchings, convulsions, and paralysis, so that the condition has been called **thyreoprival tetany**. Young animals and carnivora are especially susceptible; dogs die for the greater part in a short time after total thyroidectomy.

If the loss of the gland is at first well borne, as is the case in man, there arise in the course of months or years peculiar disturbances of nutrition, beginning with weakness and heaviness of the limbs, feeling of coldness, often also pain and transient swelling of the limbs, with loss of mental activity, leading to a **cachexia** associated with anæmia, and characterized further by pale swellings of the skin, especially of the face (Fig. 5), and marked diminution of mental powers, together with a loss of muscular strength, these symptoms finally terminating in death. The removal of the thyroid gland in childhood causes disturbances of growth, the increase in length of the bones falling below the normal or ceasing altogether (Fig. 5). Animals (rabbits and goats) that have had their thyroid glands removed soon after birth do not reach full growth and acquire an expression of stupidity.

In thyreoprival tetany the body temperature is increased; in the cachexia it is lowered.

Disturbances of thyroid function, as well as total extirpation, lead



FIG. 5. — Thyreoprival cachexia with cretin-like disturbance of development, in a man twenty-eight years old, arising after the total extirpation of the thyroid gland in patient's tenth year; length of body 127 cm. (See Grundle, *loc. cit.*)

to pathological conditions of the body. Both clinical observations and experimental investigations tend to show that the peculiar disease (Fig. 6) known as **myxœdema** (Ord) is due to changes in the thyroid. Myxœdema is a condition in which the external appearance of the patient is suggestive of thyreoprival cachexia, in that the same characteristic pale and elastic swellings of the skin of the face (Fig. 6), not pitting on pressure with the fingers, are associated with similar pale and dry swellings in other parts of the body. Further, there is a loss of intellectual power, which finds expression in an increasing difficulty in thinking and acting, dulness of the tactile sense, retardation of muscular action, and a monotonous nasal voice. Finally, a marked general weakness and often also symptoms of actual mental derangement occur,



FIG. 6.—Myxœdema (case observed by Meltzer). Age of patient, thirty-seven years.



FIG. 7.—Myxœdema. The same individual (Fig. 6) after three months of treatment with pulverized sheep's thyroid.

and death follows a gradually increasing cachexia associated with symptoms of anemia and coma.

Judging from the clinical and anatomical characteristics presented by the patients, **cretinism** (Fig. 8)—that is, the alterations in the structure and functions of the body which characterize this disease—is dependent upon disturbances of thyroid function. In support of this view is the fact that in cretins there is always present some degenerative condition of the thyroid, the organ being either enlarged and changed in structure (goitre) or atrophic. Further, the general appearance of cretins (Fig. 8) is similar to that of those individuals who as a result of thyroidectomy in early childhood (Fig. 5) have become stunted in development. The longitudinal growth of the long bones is more or less below that of the normal, while the soft parts are relatively well developed. The individual portions of the body are unequally developed, the head is relatively large, the abdomen and neck are thick, the bridge of the nose is depressed, while the nose itself is broad and stumpy; the skin is pale, flabby, wrinkled, and puffed, as if œdematously swollen, particularly over the face. The mental faculties are always feeble, sometimes markedly so. The power of speech and of understanding



words may be entirely absent, and only the less marked cases of cretinism are capable of performing work of any kind.

Since cretinism appears to be an endemic disease in certain regions, it has been assumed that an unknown local miasm, probably taken into the body in the drinking-water, causes degenerative changes in the thyroid during the period of development, and injures the organism through the disturbance of the function of this gland. There would exist, then, a miasm which has the same effect as the operative removal of the gland, and if we designate this effect as *epidemic cretinism*, we may apply the term *operative cretinism* to cachexia thyreopriva. Further, myxœdema may be regarded as a form of cretinism, which we may designate as *sporadic*, in contrast to the epidemic form.

The great importance of the thyroid gland for the general nutrition of the organism, the cerebral functions, and the development of the bones has been placed beyond all doubt by numerous clinical observations and experimental investigations. As to the exact mode of action of the thyroid, there are, however, different opinions. If an animal, after thyroidectomy, is fed with the thyroid of some other animal—for instance, that of the sheep—the injurious effects usually observed after removal of the thyroid do not appear and will occur only when the feeding is stopped. In man the administration of fresh thyroid tissue or of thyroid extracts exerts a healing influence on the thyreoprival cachexia and myxœdema (Fig. 7); and reports have been published of favorable results of the same treatment in children suffering from cretin-like disturbances of development.

Goitres (enlarged and hypertrophic thyroids) which have not yet undergone secondary degenerations often diminish greatly in size after the continued use of thyroid tissue for a number of weeks, but after the cessation of the treatment soon begin to grow again.

According to *Lanz*, the extirpation of the thyroid in hens causes a diminution in size of the eggs; feeding with thyroid causes them to increase in size.

According to the investigations of *Baumann*, the thyroid constantly contains an iodine substance, **thyroidine** or **iodothylin**, which is present in the greatest quantity in old individuals, and in the smallest quantity in very young children. Iodothylin for the chief part is usually combined in the thyroid with an albumin and a globulin body, but it may appear in a free form. The normal thyroid is

able to store up the extremely small amounts of iodine brought into the body in vegetable foods or in the drinking-water, and to convert it into the combination mentioned above. The internal administration of preparations of iodine or the treatment of wounds with such leads to a greater accumulation of iodine in the thyroid.

According to *Baumann*, iodothylin is the active element of the gland. Its employment in the treatment of goitres, myxœdema, and strumiprival cachexia, etc., has the same effect as the feeding with fresh thyroid tissue. It would appear that the organism requires iodine for its proper maintenance, and that the thyroid supplies it with the necessary iodine-combination. In regions where goitres are not commonly found (North Germany), the thyroid glands are, on the average, much smaller (from 30–40 gm.) and contain more iodine (on the average about  $3\frac{1}{2}$  mgm. instead of 2 mgm.) than in regions where goitres are numerous (Switzerland, South Germany). Whether the lack of sufficient iodine in the food and drinking-water is the cause of the hypertrophied condition of the thyroid in goitre, or whether perhaps some lower organism interferes with the specific function of the gland, cannot be said at the present time. Among the domestic animals having an especially large amount of iodine in the thyroid are the sheep, the cow, and the calf, while in hogs the iodine-content of the gland is small.



FIG. 8.—Female cretin, twenty-one years old; body-length 84 cm.; length of arm 30 cm.; circumference of skull, 52 cm. (After Virchow.)

## 88 DISEASES PRODUCED BY DISTURBANCE OF INTERNAL SECRETIONS.

*Blum* regards the thyroid as an organ whose function it is to destroy enterotoxins arising from the decomposition of albumin in the intestine.

Anatomical investigations have failed to throw any definite light upon the question of the internal secretion of the thyroid. It has been proved that the colloid produced by the thyroid cells passes into the lymph-vessels. It is probable that iodothylin is contained in this colloid substance. According to *Bruno*, the diminution in the size of the goitre after the administration of thyroid-gland-substance or of thyroiodine may be attributed to the fact that in the hypertrophic gland-tissue of the goitre which contains numerous follicles—many of which are entirely destitute of colloid, or contain but little of it, or are imperfectly developed—there occurs an increase of colloid-secretion in the fully developed follicles, and at the same time a greater abundance of colloid is passed into the lymph-stream, while the imperfectly developed follicles, on the other hand, atrophy and disappear. After the administration of active thyroid substance for a longer time, some of the secreting follicles also undergo atrophy.

According to the investigations of *Rogowitzsch*, *Stieda*, and *Hofmeister*, the extirpation of the thyroid in rabbits causes enlargement and peculiar changes in the hypophysis.

It is possible that *Basedow's disease*, which is characterized by a pulsating and highly vascular swelling of the thyroid, projection of the eyeballs from their orbits, acceleration of heart action, and great excitability on the part of the patient, is also dependent upon a diseased condition of the thyroid—namely, a *hypersecretion* (*hyperthyreosis*). In support of this hypothesis is the fact that glands so affected are rich in functioning gland-tissue; but no positive conclusions can be drawn concerning this point.

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§ 27. **Addison's Disease** is a peculiar affection, usually fatal after a course of about two years on the average, and is very probably to be regarded as the result of a *functional disturbance of the suprarenals*. It is characterized chiefly by the appearance of a light-yellow-brown to dark-brown, diffuse, and spotted pigmentation of the skin (*melasma suprarenale*), which shows itself first in the portions of the skin normally exposed, later in other parts of the body-surface and in the mucous membrane of the mouth. Even at the beginning of the disease, or even before the pigmentation of the skin, there occur loss of appetite, nausea, pain in the epigastrium, diarrhœa, constipation, and vomiting—all symptoms of a disturbed intestinal and gastric function; later, muscular weakness; and finally, nervous symptoms, asthenia, fatigue on slight exertion, headache, vertigo, fainting, epileptiform attacks, and coma. Occasionally a recognizable increase of the pigment of the skin does not occur, and the disease is characterized only by the gastro-intestinal symptoms, progressive weakness, and anæmia.

In about eighty per cent of all typical cases of Addison's disease the suprarenals are found to be diseased, in the majority of cases being changed into a caseous or fibro-caseous mass. With the exception of these changes there are no other lesions so constantly characteristic of Addi-

son's disease. There can scarcely remain any doubt that the disease of the suprarenals bears a causal relation to this disease; it may, therefore, be designated as a **suprarenal cachexia**. In what way the loss or change of the function of the suprarenal bodies acts injuriously upon the organism cannot at present be stated. It is not improbable that the suprarenal bodies, like the thyroid, produce a substance which is necessary for the preservation of the organism; or possibly poisonous substances are destroyed by them.

The literature of *Addison's disease* is exceptionally rich, but in spite of the great number of clinical and experimental investigations, the pathogenesis of the disease and the significance of the adrenals for the human and animal organism have not yet been made clear. Nevertheless, it is certain that a normal functional activity of the adrenals is necessary to the integrity of the organism. This is based not only upon clinical observations and anatomical investigations in man, but also upon animal experiments. For example, the extirpation of the adrenals in dogs, rabbits, cats, and guinea-pigs gives rise to a lowering of blood-pressure, muscular weakness, and nervous symptoms, paralysis, coma, and, if life be sufficiently prolonged, a loss of strength, and, according to Tizzoni, also an abnormal pigmentation of the mucous membranes. The administration of adrenal extract causes in animals an increase of blood-pressure, slowing of the pulse-rate, increase in the strength of muscle-contractions after nerve-stimulation, and a decrease in respiratory movements. The cause of the increase of blood-pressure is regarded by some as the effect of the extract upon the vasomotor centre (*Scymonowicz*), by others as a direct action upon the arterial walls (*Schäfer*). The contraction of the small vessels has been definitely proved. According to *von Fürth*, the active substance is hydro-dioxypyridin, which he calls *suprarenin*. Since the adrenals do not show pathological changes in all cases of Addison's disease, the view has been advanced by some investigators that the disease is dependent upon other local changes, particularly upon pathological conditions of the sympathetic and the sympathetic ganglia; yet the conditions found thus far are not adequate for such an explanation. That in a small minority of cases the adrenals appear unchanged cannot (even if all these cases had been correctly diagnosed, which is surely not probable) be accepted as valid evidence against the pathogenic significance of the degeneration of the adrenals, inasmuch as an apparently normal adrenal may functionate abnormally.

Inflammatory and degenerative changes in the semilunar ganglia or in other parts of the sympathetic, as well as in the intervertebral ganglia have been frequently observed in Addison's disease. These have been described by a number of investigators, and may be explained as an extension of inflammation and degeneration from the adrenals to the parts mentioned. To conclude from this that Addison's disease is dependent upon a disease of the sympathetic and not of the adrenals, is not sufficiently well grounded, since the disease of the adrenals actually exists while that of the nerves is found only in a minority of cases.

*Mannasse* found in preparations which, while still retaining the body-heat, were placed in solutions of chromic salts and thereby hardened, that the cells of the adrenal stand in closest relations to the veins, reaching out free into the lumen of the veins; and that in the vessels, particularly in the veins, there is present a peculiar hyaline substance, which is colored brown by the chromic salts in the same manner as are the neighboring parenchymatous cells. It is therefore possible that the cells furnish to the blood some peculiar substance. It should be stated, further, that this substance is found also in the arteries. It cannot be demonstrated in alcoholic preparations.

As a pathological condition due to the loss of a specific glandular function should be classed also those abnormal symptoms in the structure and functions of the body resulting from **castration**—that is, the removal from the body of the sexual glands. If the ovaries are removed from a woman after the age of puberty, menstruation usually ceases at once, but rarely only after some time. Sexual desire and the *erethism* accompanying the sexual act are usually diminished in intensity, but may also be unchanged. The remaining portions of the genital apparatus undergo atrophy; this is especially marked in the case of the uterus. Certain nervous manifestations may follow, the most common of which are excitement, with reddening and heat of the skin, especially of the face, often associated with attacks of sweating; these symptoms being of most frequent occurrence in the period immediately following the castration. The disposition remains unchanged or may become more cheerful, especially in those cases in which the woman is by the castration relieved of severe pain. At times depression or melancholia may follow. If the ovaries are removed or destroyed during childhood, the body comes to resemble in its build the male type; the muscles are more strongly

developed, the development of the pelvis is changed, and the breasts do not increase in size.

Castration in an adult male produces no marked change in the build of the body. On the other hand, if boys are castrated, the build of the body approaches that of the female. There occurs an increased deposit of fat, particularly on the abdomen, while the musculature is only feebly developed. The external genitals remain small, the prostate is diminished in size, and there is no growth of beard or pubic hair. The larynx remains small, and the voice is child-like. The mental powers are lacking in energy and strength.

In castrated stags the antlers are not developed; in cocks the combs, wattles, and ear-lobes do not reach normal development, while the feathers are developed to a greater extent (*Sellheim*).

According to *White, Kirby, Kümmel, Bruns*, and others, castration in fully developed animals causes a decrease in the size of the prostate; and it is said that in old men suffering from prostatic enlargement, castration may lead to a diminution in size of the enlarged prostate. Others (*Czerny, Socin*) express a less favorable opinion as to the results of castration in such cases.

In what manner the *extirpation of the sexual glands affects the entire body* has not been determined with certainty. By many authors it is assumed that, as a result of castration, the trophic influence exerted upon the tissues by the sexual glands, through the nervous system, is withdrawn. The cessation of the menses may indeed be regarded as due to the withdrawal of nervous stimuli, and the atrophy of the uterus may perhaps be dependent upon the same cause; but in general it is more likely that certain *chemical substances*, which exert a certain influence on the functions, growth, and development of the body, are formed in the sexual glands.

According to the investigations of *Loewy* and *Richter*, after castration of female dogs there occurs a lowering of the oxidation-power of the cells of the body and a decrease in the amount of oxygen used by about twenty per cent. The administration of dried ovarian substance or of oöphorin from the ovaries of the cow or hog causes an increase of the amount of oxygen consumed even greater than the average observed before the castration. Preparations of testicles showed no such influence. In male dogs the same conditions prevailed; spermin caused only slight increase in the gaseous interchange, oöphorin gave a marked increase (as much as forty-four per cent).

According to the view of *Brown-Séguard*, all glands produce an especial internal secretion, and give to the blood certain substances which are useful to the organism. He ascribes to the juice of the generative glands an especial, stimulating, and tonic influence upon the organism. According to *Pöehl*, the active substance in the extract of the sexual glands is *spermin*, a base which is found in different glands (thyroid, pancreas, ovaries, spleen), and which through its catalytic action restores the oxidizing power of the blood whenever through various causes it may be lowered, and *promotes intraorganic oxidation*.

*Zöth* and *Pregel*, who have carried out experiments with reference to the effects of glycerin extracts of the testicles of animals, report that injections of this extract increase very markedly the power of muscular contraction.

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## III. Fever and Its Significance.

§ 28. When a local organic disease takes on the character of a **general disease**, or when a disease at its very inception manifests such a character, there is seen very frequently a *symptom-complex* which is designated as **fever**. Particularly in the case of those infectious diseases

associated with symptoms of intoxication does the appearance of fever during their course play an important rôle. The characteristic sign of fever is an *increase of bodily temperature*; but accompanying this there are other symptoms, especially an *increase of the pulse-rate*, *disturbances in the distribution of the blood*, *changes in the gaseous interchange within the lungs*, and also *changes in the urinary secretion*. There is usually also a subjective feeling of illness, but this is not a necessary part of the symptomatology of fever, but an especial effect of an infection associated with symptoms of poisoning, the infection occurring at the same time with the feverish increase of temperature, or before it, or even after it.

Observation of the normal body has taught us that, in spite of changes of temperature externally and also of changes in other extrinsic conditions, the body-temperature is maintained at an average height of  $37.2\text{--}37.4^{\circ}\text{C}$ . ( $98.96\text{--}99.32^{\circ}\text{F}$ ). The absolute variation between morning and evening is  $1\text{--}1.5^{\circ}\text{C}$ . ( $1.8\text{--}2.7^{\circ}\text{F}$ ), the maximum occurring at evening.

The elevation of temperature of the body above that of its surroundings is due to the fact that through chemical changes occurring in the organism, particularly in the muscles and glands, heat is produced, and to such an extent that the temperature of the body may be raised one degree

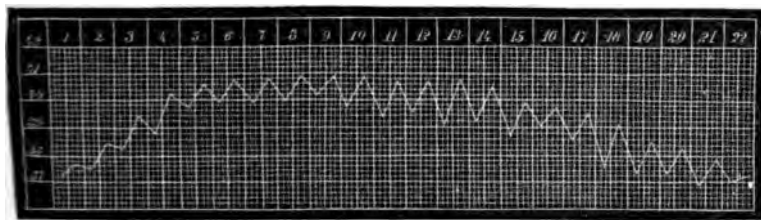


Fig. 9.—Temperature-curve of a continued remittent fever, with slowly rising and gradually falling curve (typhoid fever).

Centigrade ( $1.8^{\circ}\text{F}$ .) in half an hour. This phenomenon of heat-production is offset by one of heat-dispersion, occurring chiefly through the skin, lungs, and the excreta. Both heat-production and heat-dispersion are under the influence of the nervous system, and through its regulation of both processes a constant temperature is maintained.

On exposure to lower temperatures the heat-production is increased (chiefly through the agency of the muscles), while heat-dispersion is lessened through contraction of the cutaneous vessels and inhibition of perspiration.

On exposure to higher temperatures heat-dispersion is increased through increased frequency of respiration, dilatation of the arteries of the skin, and increased secretion of sweat.

In those conditions which we call **fever** there is a *disturbance of the regulation of heat-production and heat-dispersion*, in favor of heat-production, so that the *temperature of the body is more or less elevated above the normal* (Figs. 9–11). Elevations of temperature (rectal measurements) to  $38^{\circ}\text{C}$ . ( $100.4^{\circ}\text{F}$ .) are called *hypernormal*; from  $38^{\circ}$  to  $38.5^{\circ}\text{C}$ . ( $100.4\text{--}101.3^{\circ}\text{F}$ ), *light fever*; from  $38.5$  to  $39.5^{\circ}\text{C}$ . ( $101.3\text{--}103.1^{\circ}\text{F}$ ), *moderate fever*;  $39.5\text{--}40.5^{\circ}\text{C}$ . ( $103.1\text{--}104.9^{\circ}\text{F}$ ), *marked fever*; over  $40.5^{\circ}\text{C}$ . ( $104.9^{\circ}\text{F}$ .) (evening temperature), *high fever*; and over  $41^{\circ}\text{C}$ . ( $105.8^{\circ}\text{F}$ ), as *hyperpyrexia*.

Four **periods** may be distinguished in fever. The first, which is

known as the **pyrogenetic** or **initial stage** or **stadium incrementi**, corresponds to that time during which the previously normal temperature reaches the average height characteristic of the disease. This period is sometimes short (Fig. 10), half an hour to two hours long, and in this case is usually accompanied by a *chill*; sometimes longer (Fig. 9), one to several days, and then usually runs its course without a chill, though chilly sensations may repeatedly occur.

In the second period, known as the **fastigium**, whose duration varies according to the disease from a few hours to several weeks, the temperature reaches one or several *acme-like highest points*, between which there are more or less marked remissions.

In the stage of **decline of the fever** or the **defervescence** or **stadium decrementi**, the body-temperature returns again to the normal. If this takes place through a rapid fall of temperature (Fig. 10), it is called **crisis**; if slowly, it is termed **lysis** (Fig. 9). The former is usually accompanied by profuse sweating, and in a few hours, or at most in one to one and a half days, the temperature falls two or three degrees, occasionally as much as five to six degrees Centigrade. In lysis the tempera-

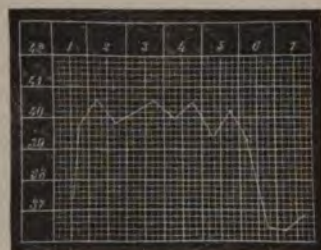


FIG. 10.—Temperature curve of a continued fever with rapidly ascending and rapidly falling curve (pneumonia).



FIG. 11.—Temperature-curve of an intermittent tertian fever (malaria).

ture falls gradually for three to four or more days; the decline may be either continuous or intermittent.

The boundary-line between fastigium and defervescence is not always sharply defined, and before the latter sets in there may occur elevations of temperature, this phenomenon being called **perturbatio critica**. If between the fastigium and defervescence there occur several days of uncertainty with striking fluctuations upward or downward, such period is known as the **amphibulous stage**. Occasionally there may occur a short period in which the temperature is somewhat lowered, but yet remains high above the normal, to sink after a few days to the normal either rapidly or by a gradual decline.

In the stage of **convalescence** the temperature returns to the normal condition. The heat-regulation is during this time still imperfect, so that often slight elevations and not infrequently subnormal temperatures occur.

If during the course of a fever the daily variation is slight, so that the difference between maximum and minimum is not more than that under normal conditions, the fever is called a **continuous fever** (*febris continua*) (Fig. 10). If the differences are greater, the fever is termed **subcontinuous** (*febris subcontinua*), **remittent fever** (*febris remittens*) (Fig. 9), or **intermittent fever** (*febris intermittens*) (Fig. 11).

In the last-named, afebrile periods (*apyrexia*) alternate with periods of fever, each *paroxysm* having an initial period, a fastigium, and a defervescence. In the infectious disease known as *febris recurrens* there is first a continuous fever, which after a few days falls by crisis; after about a week or so a second rise of temperature occurs, which may be followed by a second stage of *apyrexia*, and this by a third period of fever.

Many diseases—such as typhoid fever, pneumonia, measles, relapsing fever, etc.—are characterized by a typical temperature-curve; others—as pleuritis, endocarditis, diphtheria, tuberculosis, phlegmon, etc.—have no typical course of fever.

The elevation of the body-temperature in fever is dependent primarily on an increase in heat-production through increase of the chemical changes occurring in the body. The respiratory interchange of gases—the excretion of carbonic acid (Liebermeister, Leyden) and the taking-up of oxygen (Zunz, Finkler)—is increased, a proof that the oxidation-processes and with these also the heat-production are increased. At the same time the excretion of nitrogenous elements in the urine (urea, uric acid, creatinin) is increased—on the average about from seventy to one hundred per cent, under certain conditions even as much as threefold. There is also an increased destruction of the albuminoid substances of the body, the albumin of the organs, even in the latent period of the fever (Naunyn).

The increase of heat-production varies in different fevers, but in general does not reach that degree which can be produced by excessive muscle-action and over-feeding with albumin. It is at its highest point at the time of the initial chill, in that the violent muscular contractions thereby produced may increase the production of heat.

The second cause of the elevation of the body-temperature is *deficient heat-dispersion*. At the height of the fever the patient as a rule gives off more heat than the normal individual, but this dispersion is not sufficient to offset the excessive heat-production. Heat-production is constantly increased; heat-dispersion is irregular.

In the initial stage the cutaneous vessels are contracted as a result of stimulation of the vasomotors, the skin is pale, the heat-dispersion slight, under certain conditions even less than normal.

Chills occur when, through the contraction of the peripheral arteries, the supply of blood, and consequently the heat-supply, to the cutaneous nerves is suddenly diminished, while in the interior of the body the temperature is rising.

In the **second stage of fever** the skin is often hot and reddened, and in certain diseases sweating occurs; but the increased heat-dispersion thereby produced is not sufficient to lower the temperature to the normal. The increased excitability of the vasomotors or the deficient irritability of the vaso-dilators (Heidenhain, Naunyn, Senator) is also present during this period, and as a result the skin-temperature, as well as the heat-dispersion, varies greatly. The skin is at times pale and cold, at other times red and hot, and the hands may be cold while the trunk is hot. The centres governing heat-dispersion are therefore acting faultily.

In the **period of defervescence** the relations of heat-dispersion and heat-production are changed in favor of the former. The cutaneous vessels become dilated, the skin gives out a great amount of heat from the abundance of blood circulating through it, and when the critical fall of the fever occurs there is usually profuse sweating.

The **cause of fever** is not known with certainty, yet this much can be said, that fever is most frequently the *result of the entrance of a harmful agent into the fluids of the body*. In many cases this harmful agent arises demonstrably from a local focus—for example, from erysipelatous and phlegmonous inflammations of the skin. Experimentally, fever may be produced by very different procedures—for example, through the infusion into the vessels of an animal of blood from one of another species, through the injection of animal or vegetable substances that are beginning to decompose (Billroth, Weber), and through numerous infections. In man, the *infectious diseases*, which are regarded as due to specific micro-organisms multiplying in the body, are in particular characterized by fever.

It is probable that the parasites multiplying within the body cause an increased tissue-destruction, either directly or through the production of unformed ferments, and that at the same time substances are produced which act as *poisons* upon the central nervous system. The action of the latter may be assumed to be of such a nature that, on one side, the activity of the muscles and glands, and consequently the heat-producing metabolism, are increased; while, on the other hand, through the diminished and disturbed functions of the nerves governing sweating, as well as of the vasomotors, the processes of heat-dispersion fall behind those of heat-production. Further, though the organism makes an effort to regulate the temperature, it is no longer able to maintain it at the normal level, because of the disturbances of the regulating apparatus. What share in the increase of body-temperature is due to the direct action of bacteria and of the ferments formed by them, or what share is due to the increase of metabolism, through the stimulation of the nerves as well as by disturbance of heat-dispersion, cannot at present be determined. It is, however, certain that the factors vary in different cases. That under certain conditions, changes in the nervous system without contamination of the tissue-juices are in themselves sufficient to cause a feverish increase of temperature, is shown by the fact that fever may occur in epileptic attacks, in the periods of excitation occurring in the course of progressive paralysis, after severe frights, after the passage of a catheter into the bladder, etc. According to the investigations of Richet, Aronsohn, and Sachs, a marked increase in body-temperature with increase of the respiratory interchanges of gases and increased excretion of nitrogen (Aronsohn and Sachs) may be produced in animals by a puncture which passes through the cerebral cortex and strikes the corpus striatum. The same phenomenon may be produced also by electrical stimulation (Aronsohn, Sachs) of the same portion of the brain. Nevertheless, fevers dependent upon nervous disturbance are rare, and are overshadowed in importance by those caused by infection.

The rise of temperature in fever is usually accompanied by an **increase in the frequency of the pulse-rate**; but in some cases this effect of the elevation of temperature may be so greatly modified through stimulation of the vagus—as, for example, in basilar meningitis—that the pulse-rate may be lowered. The pulse is at one time full and bounding, at another time small because of weakened contractions of the heart.

The impairment of the contractions of the heart-muscle is dependent partly upon the constant high temperature, partly upon poisonous substances, which are produced by the morbid processes peculiar to the especial disease, and which exert a harmful influence upon the muscle-substance of the heart or upon the nervous system.

In diseases accompanied by fever there is usually a marked sensation of illness with a heavy feeling in the head. In severe fevers there occur clouding of consciousness, symptoms of excitation and depression, hallucinations, delirium, apathy, involuntary evacuations, tremors of the hands, convulsions (in children), etc. The muscles of the body become weak and not infrequently painful. Digestion is decidedly impaired; the appetite for food is slight, but on the contrary there is great thirst; the mouth is dry. There is an increased frequency of respiration; after the appearance of muscular weakness the respiratory movements are superficial. The excretion of urine is usually diminished; the amount of urea in the urine is increased, while that of sodium chloride is diminished.

In prolonged fevers there is marked wasting of the body, in that a large portion of the albuminous material and fat of the body is destroyed.

To what extent these symptoms in individual cases are dependent upon the increase of temperature or to what extent upon the damage to the organism caused by the specific morbid process, it is difficult to say, but the marked effects upon the nervous system must for the greater part be regarded as a result of the infection and intoxication.

Death results most often from cardiac insufficiency, but it may be brought about also by the severity of the infection—that is, by the changes in the body-fluids (through their influence upon the nervous system), by the wasting of the strength, as well as by an excessive elevation of temperature to 43°, 44°, or 45° C. (109.4°, 111.2°, and 113° F.). It should, however, be remarked that under certain conditions very high temperatures may be borne for a length of time without fatal results, and that the death following very high temperatures cannot be ascribed to the abnormal temperature alone, but is rather to be regarded in part or wholly as the result of the infection (see § 3).

The questions concerning the nature of fever, which *Galen* designated as *Calor præter naturam*, have been much advanced during the last decades by numerous clinical and experimental investigations. From these we have learned of the associated disturbances of metabolism, the increased consumption of oxygen, the increased excretion of nitrogen and carbon compounds, as well as of the disturbances of the heat-dispersion. If we, in spite of this knowledge, do not yet possess a full understanding of all the morbid processes which in a given case may cause fever, we may attribute this to the fact that the *causa efficiens* of fever is not a single entity, but may be one of many different factors, and that the feverish elevation of the body-temperature does not always occur in exactly the same manner. The increase of the tissue-changes and oxidation-processes within the body is not always brought about in the same way. Further, the disturbance of heat-dispersion through radiation from the skin and the evaporation of water is not always the same, but changes, not only in the course of one febrile disease, but also in different forms of fever. Correspondingly, the rôle played by the nervous system in the occurrence of the feverish increase of temperature is not the same in every case. According to *Senator*, there is, in fevers, no harmony between the regulation of heat and metabolism; and we must therefore assume that heat is developed through other processes than those leading to the production of urea and carbonic acid. According to *Herz*, heat is set free by the changes in the arrangement of the molecules of the cell-protoplasm, which occur in many of the cells in fever patients, and which lead to the destruction of protoplasm. Further, heat may be liberated by processes of swelling and coagulation of the protoplasm, while at the same time the diminished activity of the regenerative processes in fever occasions a loss in the storing-up of latent heat. On the other hand, *Krehl* and *Marthes* are of the opinion that oxidation forms the sole source of heat.

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## CHAPTER III.

### The Protective and Healing Forces of the Human Body. The Acquiring of Immunity.

#### I. The Natural Protective Contrivances, Protective Forces, and Healing Powers of the Human Organism, and their Action.

§ 29. The human organism is not entirely defenceless against the many harmful influences to which men during the course of their lives are exposed. It possesses various **protective contrivances** and **protective forces**, by which it is able in many cases to ward off the injurious agent, or at least rapidly to counteract its harmful influence, so that a disease may be either wholly prevented or confined to a slight local lesion of much less severity than the disease usually produced by the particular injurious agent. As the mode of action of different injurious influences varies greatly, so does the manner of defence likewise vary greatly. The protective forces may act at very different times—that is, sometimes even before the tissues have been damaged, at other times after the injurious action has reached a certain stage, and threatens, either through direct extension or through metastasis, or through poisoning of the body-fluids, or through disturbance of function, to spread further through the body.

When the environment of the body becomes relatively cold or relatively warm, those *regulating functions* are brought into play through which the organism can *increase or diminish heat-production and heat-dispersion*, and in this manner protect itself within certain limits against the influence of the external temperature. If these regulating functions are imperfectly performed, as in consequence of alcoholic intoxication, the individual may more easily die from the effects of cold than when under normal conditions.

We cannot speak of special protecting contrivances against gross *mechanical influences*; yet it is to be noted that the tissues by virtue of their physical properties are fitted to offer resistance to numerous forms of traumatism without receiving injury. If small, firm bodies, such as dust-particles, reach the mucous membrane of the respiratory or intestinal tracts, the *epithelium* forms a protective barrier against their entrance into the tissue-spaces. Further, if ciliated epithelium is present, the dust-particles may be carried away by the *movements of the cilia*, or they may become surrounded by the *mucus* produced by the epithelium and mucous glands, and in this way are transported out of the body.

Not infrequently there appear cells on the surface of the mucous membrane which encompass the dust-particles, and, taking these up into their substance, are carried away with the secretion of the mucous membrane. This phenomenon, known as *phagocytosis*, is observed on the mucous membranes of the pharynx and respiratory tract and in the alveoli of the lungs. The active agents participating in it are not only



the wandering-cells which pass from the tissues to the surface, and are derived chiefly from the blood-vessels and also from the nodes of lymphadenoid tissue in the mucous membrane, but epithelial cells as well. The peculiar phenomenon of phagocytosis depends upon the fact that the cells can, by movements of their protoplasm, take up little particles, which, like insoluble dust, exert no harmful influence upon the cell-protoplasm. If these cells laden with dust pass outside of the body, the taking-up of the dust by the cells appears to be a useful activity which aids in the cleansing of the organs from dust. If the dust-laden cells, on the other hand, as happens particularly in the lungs, pass into the lymph-channels and are deposited along their walls or are carried to the lymph-glands—that is, if a metastasis of the dust-containing cells into the internal organs takes place—the taking-up of dust by these cells appears in a less favorable light; and we can regard this act as a useful phenomenon only through the consideration that the infiltration of the pulmonary connective tissue and lymph-glands with dust is less harmful than the deposit of dust on the inner surface of the alveoli.

When dust-particles, free or enclosed in cells, reach the *lymph-glands*, they are arrested and deposited in the cells of these glands, so that the lymph-glands may be regarded as trustworthy *filters*, which guard the blood and the internal organs from the entrance of dust.

Against the *action of poisons* the human body is able to protect itself in various ways. In the case of corrosive poisons the *horny layer* of the epidermis and the *mucus* of the mucous membranes offer a certain protection; and under certain conditions a marked increase in the production of mucus—in the stomach, for example—may greatly diminish the harmful effects of a corrosive fluid. Through a transudation of fluid from the blood-vessels on to the surface of the mucous membrane a caustic fluid may be so diluted as to modify its action. On the other hand, the injurious substance may be thus spread over a greater surface, and thereby cause a more widespread damage to the tissue.

On many poisons, abrin, ricin, the toxins of cholera, tetanus, and diphtheria, and snake-venom, the digestive juices have such an influence that doses invariably fatal when injected under the skin may be borne with impunity when taken by the mouth. According to Ransom, guinea-pigs are able to withstand, when administered by the mouth, an amount of tetanotoxin equivalent to three hundred thousand times the minimal fatal dose. According to Nencki and others, this *neutralization of the poison is produced by the digestive enzymes*, at one time chiefly through the pepsin, at another time through the trypsin and the mixture of the pancreatic juice with the bile. It is probable (Nencki) that the digestive enzymes cause a slight change in the molecules of the toxin, similar to the change of albumin into albumose; and the products arising from the toxins may accordingly be termed *toxoses* or *toxoids*.

In the case of those poisons which after their entrance into the body-juices act injuriously upon the blood or the nervous system, a favorable counter action on the part of the organism may be given partly by a *rapid excretion of the poison* through the kidneys, liver, and intestine, and partly through a *chemical change of the poison*. This method of protection is effective only when it is accomplished before any injury has been produced by the poison.

Of *natural immunity against poisons* or *natural resistance to poisons* we know but little at present, yet there is no doubt that many poisons are poisonous only for certain organisms, and it is probable that man is re-

sistant to many poisons which are injurious to certain animals. The same thing holds true especially of the toxic proteids and the organic bases, as they are formed by bacteria or by higher animals (snakes) and plants. If we consider that many animals are only slightly or not at all susceptible to poisons which have marked action upon the human body—for example, the hedgehog is immune or resistant to cantharidin and the bite of poisonous snakes respectively; birds are immune against atropine and opium; goats against lead and nicotine; while dogs, rats, or other animals used for experiment show a disproportionately greater resistance to bacterial poisons or plant-alkaloids than does man—so it is very probable that the reverse is also true. The natural immunity of man against many of the infectious diseases of animals must depend upon a resistance to the toxalbumins and toxins produced by the particular bacteria. According to Ehrlich, this resistance to poisons may be explained by the theory that the particular toxin possesses no chemical relationship to any one of the bodily elements.

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§ 30. Against the infections and intoxications caused by parasites the human organism possesses various **protective contrivances** and **powers of defence**; and these play a very important rôle in the diseases caused by bacteria. In the first place, man possesses a **natural immunity** against many of the micro-organisms pathogenic for animals (for example, swine-plague, swine-erysipelas, symptomatic anthrax), so that the given micro-organisms are not able to reproduce within the body, either because they do not find in human tissues the necessary conditions of life, or because the presence of certain chemically active substances hinders their increase or kills them directly. For the protection of the body against the pathogenic micro-organisms there are available certain forces, which, according to their activity, may be divided into four groups: the first hindering the entrance of bacteria into the tissues; the second hindering the unlimited local spread of those bacteria which have gained entrance and have begun to multiply; the third preventing the entrance of bacteria into the blood and their metastasis; the fourth hindering intoxication, or at least weakening it, and reducing it to a low degree.

For the prevention of the **entrance of pathogenic bacteria into the tissues** the same properties of tissues are effective as those hindering the entrance of dust; and in such capacity the *protective epithelium* and the *mucus* play a very important rôle. In the respiratory tract the *movements of the ciliated epithelium* also furnish protection, and in the stomach the *poisonous action of the gastric juice* upon many pathogenic bacteria is an efficient means of defence. There can be no doubt that many pathogenic bacteria are not able to penetrate into the tissues, not only through

the uninjured external skin, but also through an unwounded mucous membrane, without some assistance favoring colonization and reproduction, and that the stomach secretion not infrequently hinders the activity of the bacteria (pneumococcus, cholera spirillum), or even kills them.

It appears also that the mucus secreted by the mucous membranes not only can envelop the bacteria, hinder their entrance into the tissue, and favor their removal, but that—what is of much greater importance—the mucus acts upon the bacteria, causing them to degenerate, either in that it contains substances which are injurious to the bacteria or in that it offers an unfavorable medium for the growth of the bacteria. In this way, according to Sanarelli and Dittrich, pus-cocci, cholera-spirilla, and pneumococci gradually lose their virulence and die in the mucus of the mouth-cavity, while diphtheria-bacilli apparently are not injured by mucus. In the secretion of the vagina and uterus, various kinds of bacteria likewise soon die.

Not every pathogenic organism, therefore, which gains a foothold upon the skin or upon any of the accessible mucous membranes or gains entrance to the lungs produces an infection. It has been shown through repeated investigations that in normal individuals there not infrequently occur in the upper respiratory passages and mouth-cavity not only harmless bacteria—i.e., those which cannot reproduce in human tissues—but also those which can undoubtedly produce disease, as, for example, cocci which cause suppuration or those which are able to cause croupous inflammation of the lung. It is, therefore, to be assumed that bacteria which are found upon the mucous membranes and have perhaps multiplied there often die and are carried away without having produced infection. This occurs especially in the case of the cocci above mentioned, and tubercle-bacilli, as well as in the case of cholera-spirilla which suffer when brought into contact with the acid secretions of the stomach. Finally, it may also be assumed that of the pathogenic bacteria entering the alveoli of the lung in the inspired air, many do not reproduce but die.

In the case of a wound, uninjured *wound-granulations* offer a relatively secure protection against infections; in the first place, mechanically, by means of the thick layer of cells (Noetzel); and further, from the fact that the tissue-juices which escape from the granulations and infiltrate the same may weaken the virulence of various bacteria (Afanassieff).

When **bacteria have succeeded in gaining entrance locally and have begun to multiply**—no matter whether they have passed through the epithelium without the aid of any other influence (typhoid-bacilli, cholera-spirilla), or whether they have passed into the connective tissues through the medium of small wounds (tetanus-bacilli, pus-cocci, cocci of erysipelas, tubercle-bacilli)—if they produce further effects either through local destruction of tissue or through the poisoning of the fluids of the body, there may be brought into action on the part of the body certain **counter-influences** *which either hinder the further development of the bacteria or weaken or even completely destroy the poisons produced by them.* The first-named restraining influence must naturally depend upon local conditions, either upon vital tissue-processes or upon the effects of chemical substances.

As previously mentioned, the development of bacterial colonies gives rise to local tissue-degenerations, inflammation, and tissue-proliferations—all of which are processes in which the amount and composition of the fluids found in the affected region, as well as the cells themselves, are changed. Since in some of these cases a destruction of the bacteria has

been observed, and the infection not infrequently comes to an end through the complete disappearance of the bacteria, the death of the latter must be regarded as dependent upon local conditions.

Many writers ascribe the **prevention of the further spread of the infection** and the **destruction of the bacteria**, in local foci of growth, to the activity of cells which collect at the seat of infection and take up the bacteria into their protoplasm—that is, to **phagocytosis** is ascribed the most important rôle in the protection of the body against bacterial invasion. According to Metschnikoff and others, the amœboid cells of the body carry on a fight against the foreign invaders and endeavor to overcome them and destroy them. Such a characterization of the phenomena of phagocytosis is not supported by the actual facts, and can be regarded only as a poetical manner of expression by which consciousness and will-power are attributed to the amœboid cells of the body (the leucocytes and the proliferating tissue-cells)—which attributes it is evident do not exist. Scientifically considered, the gathering of the cells at the infected focus and the resulting phagocytosis represent simply an expression of certain processes which are natural to the amœboid cells, and which are dependent upon the fact that the cells under the influence of mechanical, chemical, and thermal influences perform certain definite movements. We know through numerous investigations that the motile cells of the body are in part attracted, in part repelled or paralyzed by means of chemical substances in certain concentrations of solution (see the Chapter on Inflammation); and, further, that contact with hard bodies can stimulate them to the sending-out of protoplasmic processes.

Such phenomena are designated as **negative** and **positive chemotropismus** or **chemotaxis** and as **tactile irritability**. We must assume that the bacteria multiplying within the tissues act upon the amœboid cells through the chemical substances which they produce, sometimes repelling or paralyzing, sometimes attracting, in the latter case affording conditions favorable for phagocytosis. This assumption is in harmony with the actual behavior of the cells in different local infections, in that the bacteria in one case are taken up by the cells, in another they are left undisturbed.

If *phagocytosis* of the cells, in infections, be regarded as one of the vital phenomena of cells, it may be interpreted as a *process designed for the taking-up of nourishment*; and this interpretation would suffer only one exception, whenever microparasites, themselves capable of motion, penetrate by reason of their own activity into the cells.

The *result of the taking-up of bacteria into cells* depends in a particular case partly upon the properties of the devouring cells, partly upon the properties of the microparasites, and can result as well in the death and dissolution of the parasite, as in the death of the cells; or in a symbiosis of the cells with the parasites, the latter living within the cells unchanged and giving rise to no disturbance. In the first-named case the phagocytosis may be regarded as a curative process which hinders the multiplication and spread of the bacteria. In the second and third cases, on the contrary, the phenomenon is useless for the prevention of the spread of the parasites; indeed, there are cases (leprosy and to some extent also tuberculosis) in which the parasites find favorable conditions for development inside of the cells, increase within them, and finally cause their destruction. If the cells containing bacteria remain preserved for a length of time, they may wander with the enclosed bacteria to other parts of the body, in this way effecting a metastasis.

*Phagocytosis is therefore only of slight significance as a protective force in a certain number of cases; yet it cannot be doubted that the phagocytes in certain infections take up, not only dead or dying, but also living bacteria not yet injured by other agents, and can cause their death. The collection of great numbers of cells in the infected tissue may, through the close packing of the lymphatics, offer a certain mechanical hindrance to the spread of bacteria, yet the protection so afforded is frequently insufficient.*

If bacteria, either free or enclosed in cells, pass from the lymph-vessels into the **lymph-glands**, the latter act as **filters**, as in the case of dust, and retain the bacteria; but the protection which they offer is sufficient only when the bacteria so collected in the lymph-glands are hindered in their reproduction and are killed by the influence of their surroundings. The destruction may be accomplished under the influence of phagocytosis, but *in many cases phagocytosis is possible only when the bacteria are weakened or have already been killed.* Further, the taking-up of living bacteria by the cells is not always followed by destruction of the bacteria, but there very frequently takes place an intracellular multiplication of the bacteria.

More important than phagocytosis for the prevention of the spread of bacteria and other microparasites is the influence exerted by certain **chemical substances** in solution in the tissues. Since the saprophytic, non-pathogenic bacteria, when injected into living tissue, are killed within a very short time, we must assume that *in the tissues there are present chemically active substances which are poisonous for many bacteria and can cause their rapid destruction.* Further, since many pathogenic bacteria ordinarily increase only locally (tetanus-bacilli, diphtheria-bacilli, cholera-spirilla) and after a certain time perish within the infected area, without spreading further through the body, it is very probable that *the tissues of the body also contain substances which are poisonous for many pathogenic bacteria* and prevent their spread. The phenomena observed in local infections speak also for the fact that such substances at times are formed in increased amounts or are aided in their action by newly-formed poisonous substances. It is, furthermore, probable that the crowding of cells which takes place in the infected tissue or in its neighborhood leads also to an increase in the production of these poisonous substances, and may thereby hinder the spread of the bacteria; nevertheless, attention should be drawn to the fact that in many infections the spread of bacteria through the tissues comes to a standstill in places where there has been no crowding together of cells. It is also a fact that in many infections the spread of bacteria through the body by metastasis is either wholly wanting (tetanus, diphtheria) or at least is insignificant in comparison with the local infection, and is usually followed by relatively insignificant local changes. The explanation of this fact is to be sought, not so much in the assumption that local tissue-changes, through the formation of special chemical substances or through the aid of mechanical substances or through the aid of mechanical hindrances—such as that afforded by a wall of cells—hinder the entrance of bacteria into the lymph and blood, but much more in the fact that *there are present in the lymph and blood itself certain forces which are able to injure and weaken the bacteria taken up into these fluids or to destroy them.*

The **hostile action of the blood on bacteria** has been ascribed to the phagocytic action of the leucocytes; and this theory is supported by the

fact that such a phagocytosis can be demonstrated very frequently in acquired infections or after the artificial introduction of bacteria into the blood; and, further, by the fact that the bacteria within the blood, enclosed in cells, may often be carried out of the blood-vessels and deposited in different organs—for example, the spleen, liver, bone-marrow, and the kidneys—and there destroyed or excreted from the body. These observations do not warrant the conclusion that phagocytosis forms a protection against the spread of bacteria in the lymph and blood; indeed, in those very cases in which a transportation of bacteria through the blood does not take place, phagocytosis is also absent; while on the contrary, the entrance of bacteria into the blood, and the multiplication of the same inside of the blood-vessels, is very often accompanied or followed by phagocytosis. Here, again, phagocytosis is of the nature of a secondary phenomenon which occurs when there are present in the blood bacteria or protozoa, which like bland dust-particles are not able to prevent their being taken up into the bodies of the leucocytes—that is, they exert a positive attraction on the phagocytes.

When bacteria are taken up by cells, they either die or continue to multiply inside of the cells, according to their properties and their condition at the time of the phagocytosis.

The forces which are able to hinder the development of bacteria in the *blood* are believed by the majority of writers to depend upon the presence of **antibacterial chemical substances**, which belong to the albuminoid bodies, and are designated as the **protective albuminoid bodies** or **alexins** (Buchner) or **mycosozins** (Hankin).

Emmerich and Buchner assume that the alexins of the blood are albuminoid bodies, having an action similar to that of enzymes, and therefore class them with the **enzymes**. This view finds acceptance with other authors. On the other hand, Baumgarten and Walz, as well as A. Fischer, oppose the view that there are chemically active protective substances in the blood; and hold that the natural immunity of the tissues and blood against certain bacteria is dependent upon the fact that the bacteria do not find the necessary chemical conditions for their development and reproduction.

So far as conclusions can be drawn from the behavior of the human and animal organisms in infectious diseases, we may assume *that in the blood of man there are always present protective chemical substances, that is, alexins*, particularly so against bacteria which never or only exceptionally enter the blood; and *that others, on the contrary, are produced only during the course of an infection*, so that not until a certain stage of the infection does an inhibition of the development of the bacteria, through the formation of antibacterial substances, occur. In favor of such hypothesis speaks the fact that many bacteria (typhoid-bacilli, cholera-spirilla, pus-cocci) possess at first their full virulence when distributed through the body by the blood, but later suffer a loss of virulence and finally die.

The protection which the *alexins of the blood* afford the organism is restricted to certain diseases; that is, to those infections in which the multiplication of the bacteria is always confined to a limited area, or in which at least the transported bacteria suffer a marked decrease of virulence. Against many infections the peculiar degenerative action of the blood upon bacteria is either wholly wanting or, in case it is present, is easily overcome, especially so in those infections in which the bacteria increase in the blood itself (anthrax), as well as in those in which the

bacteria do not increase in the blood, but suffer no decrease of virulence after metastasis (tuberculosis, leprosy, infections with pus-cocci).

The **means of protection** which the organism possesses **against the poisons produced in the tissues by bacteria** are to be found, first, in the possibility of a rapid **excretion of the poisons** by the kidneys, or, under certain circumstances, also by the stomach, intestine, and skin; and this action may in certain cases suffice to prevent a fatal poisoning. Further, in certain infections there is evidently an antagonistic action on the part of the organism, in the sense that certain poisons are either destroyed or neutralized through the action of **counter poisons** or **antitoxins**; or that the toxins and antitoxins combine to produce non-poisonous substances, or that the metabolic products of the tissues protect the latter from the action of the toxins.

The *antibacterial properties of the blood and lymph* against certain bacteria have been demonstrated conclusively by the experimental investigations of various writers. These experiments have shown that the bactericidal action of the blood of a given animal is exerted only upon certain forms of bacteria and never upon all; and that this action is subject to individual variations.

According to the investigations of *Fodor, Petruschky, Nuttal, Ogata, Buchner, Behring, Nissen, Pansini*, and others, the blood and the serum from dogs, rabbits, and white rats are capable of rendering the anthrax-bacillus harmless, and even of killing it; but this action is a limited one, so that after the introduction of a large number of the bacilli into the blood taken from the vessels, the bacilli after a time begin to multiply. Defibrinated blood of dogs and rabbits can destroy the cholera-spirillum and typhoid-fever bacillus; but, on the other hand, has no effect upon the different pus-cocci, and against proteus; the same is true also with regard to the blood-serum. Human blood or blood-serum can kill typhoid-bacilli, diphtheria-bacilli, and the bacilli of glanders. If the bactericidal properties be exhausted, these bacteria may grow luxuriantly in the blood or serum. Heating of the blood-serum to 55° C. deprives it of its bactericidal properties; the enzyme is destroyed (*Buchner*).

According to *Moxter*, there are two substances concerned in the bactericidal action of the animal fluids; one of which disappears at a temperature of 60° C., while the other remains preserved.

*Baumgarten* and *Walz* regard the fact that different bacteria which have been passed into the blood or blood-serum do not develop at all, or show but partial or delayed growth and a great diminution in numbers when cultivated upon plates, as in no manner speaking for the presence of bactericidal substances in the blood. According to their view, the second transplantation into another culture-medium causes a disturbance of the processes of assimilation and osmosis. There arise in consequence plasmolytic changes in the bacteria present in the serum; during the pouring of the plates the already injured cells die from disturbances of assimilation. This view is also held, supported by experimental investigations, by *A. Fischer*. On the other hand, it is to be noted that *A. and H. Kossel* have demonstrated that certain products of animal cells (nucleinic acid, protamine) possess bactericidal properties.

*Hankin, Kanthack, Denys, Hahn, Löwit*, and others assume, on the ground of experimental investigations, that the *alexins* are produced by the leucocytes. *Kossel* holds it as possible that the nucleinic acid present in the leucocytes in relatively rich amounts plays a rôle in the destruction of the bacteria. *Noenke* believes that the eosinophile cells of the bone-marrow in particular produce bactericidal substances. It is not possible at the present time to draw a definite conclusion as to the part played by the colorless cells of the blood in the defence against infections.

According to *Bitter*, the bactericidal substance found in organs—that derived from the lymph-glands, spleen, and thymus—is to a certain extent different from that of the blood and the blood-serum, and therefore does not originate wholly in the blood. It is certain that the bactericidal action of the blood is not the only protective influence which can oppose the spread of an infection, or wholly prevent it, and confer immunity.

According to observations of *Czaplewski*, anthrax-bacilli in an infected organism, which have been taken up into leucocytes, degenerate as a rule more slowly than those lying free in the blood and tissue-juices. It appears, therefore, as if under certain conditions the cells afford to the bacteria which they enclose a certain degree of protection from the bactericidal substances of the tissue-fluids.

The *antitoxins* which render the bacterial poisons harmless are usually formed first

during the course of the infection; but, according to the investigations of *Wassermann*, *Abel*, *Fischl*, *von Wunscheim*, and others, the serum of healthy men also contains such substances. Serum which contains the antitoxin against a certain toxin—as, for example, that against the diphtheria-toxin—can be a good culture-medium for the given bacteria; the antitoxin does not destroy the bacteria.

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See also Literature to §§ 31 and 32.

§ 31. *The healing-powers of the human body are furnished by those life-processes which are able to compensate for the disturbances and changes caused by disease, and to render harmless or to remove any harmful agent that may still be present in the body. If portions of tissue have been destroyed, the healing consists essentially in the removal of the changed and dead tissue, and its replacement by new tissue.*

When from any cause the temperature of the body becomes abnormally low or abnormally high, compensation may be effected in such a way that through the suitable regulation of the heat-production and heat-dispersion the temperature of the body may be brought back to the normal. If through trauma a portion of tissue is destroyed, the organism may repair the defect either through the local production of new tissue (*regeneration*) or by a corresponding increase in other similar tissues (*compensatory hypertrophy*).

If poisons enter the body and produce symptoms of intoxication, healing can follow only through the rapid *excretion* of the poison, or its *destruction* or *neutralization* within the body; while at the same time the damaged tissues, under the influence of normal nutrition, again return to their normal state, existing defects being properly compensated.

In infections the *healing processes* follow directly upon the *action of the protective forces*; indeed, the action of the latter constitutes the first stage of healing; *the protective and healing processes are in part identical*. If the *alexins* are able to hinder the development of bacteria, and if the weakened bacteria are dissolved and destroyed in the tissue-fluids, the first step in the healing process will have been accomplished, in that the *causa efficiens* has been removed. If the *massing together of cells* in the infected tissue forms a protecting wall against the spread of bacteria, or if the latter are held back in the lymph-glands and there destroyed, such phenomena are to be regarded as processes which prepare the way for the healing. *Phagocytosis* may also aid the healing-process. In a similar manner the *removal of the poisons or the bacteria which have gained entrance to the blood* through the excretory organs, kidneys, liver, stomach, and intestine, not only acts as a protection against the further localization of the disease and against increased intoxication, but also makes possible, through the removal of the injurious agents, the restoration of the already damaged tissues.

In many infectious diseases the healing influence of protective substances already present in the affected body is supplemented by the **appearance of new substances foreign to the normal organism**, which as **bactericidal substances** and as **antitoxins** antagonize both the infection and the intoxication. These *counter-poisons* are formed either by the tissue-cells and the blood, which through the infection have been placed under altered conditions of life, or they have been formed by the bacteria themselves; they spread throughout the tissue-juices, and thus hinder the further extension and multiplication of the bacteria.

The action of these **anti-bodies** consists either in the inhibition of bacterial growth or the destruction of the bacteria, or in the destruction and neutralization of the poisons produced by the bacteria, or in their combination with the latter to form inert, non-toxic substances. It is also possible (see § 32) that in certain infections they render the tissues insusceptible to the bacterial poison.

The cause of the *healing of infectious diseases* is most frequently referable to the fact that *chemical substances exert an antagonistic action against the intoxication*, and that the bacteria are prevented from further development and so die out. It has been demonstrated, however, that in many cases the bacteria may survive and probably also produce poisons, which, however, are harmless because of the presence of the antitoxins. In individual cases the theory appears admissible that a lack of proper nutritive material causes the death of the bacteria; as is perhaps the case in localized foci of infection (tuberculosis), in which the bacteria, enclosed in dead or slowly degenerating tissue, may remain for a long time without being able to escape to new tissues for food material. Further, such changes in the composition of the tissue-juices may be produced that the bacteria no longer find the proper conditions of nutrition. Finally, it is also conceivable that bacteria, from intrinsic causes within the bacterial cell itself, may no longer multiply, and so die out.

According to the investigations of *R. Pfeiffer*, which have been confirmed by *Sobernheim*, *Dunbar*, *Löffler*, and others, the blood-serum of animals rendered immune to typhoid-bacilli or cholera-spirilla, or that of human beings ill or convalescing from typhoid and cholera, contains, besides antitoxins, also a *specific bactericidal substance* (*lymogenous substance* of *C. Fraenkel*). This body possesses the power, when the serum is added to a virulent bouillon-culture, so to change the culture that the bacteria, when injected into the peritoneal cavity of experimental animals, rapidly break up into minute globules and are dissolved.

According to the investigations of *Gruber*, *Durham*, *Pfeiffer*, *Kolle*, *Sobernheim*, *Widal*, *C. Fraenkel*, and others, the blood-serum of individuals ill, convalescing, or entirely recovered from typhoid or cholera, exerts a damaging influence upon typhoid-bacilli or cholera-spirilla respectively; this influence being of such a nature that in bouillon-cultures the bacteria so affected become motionless, clump together, sink to

the bottom of the vessel, and are destroyed. When the serum is added to a hanging drop of bouillon-culture, the rapidly-moving vibrios at once become motionless and collect in little heaps. *Gruber* believes that this phenomenon is to be explained by a swelling and bursting of the membrane of the bacterial cell, and assumes that this change enables the alexins to destroy the bacteria present in the body. He therefore designates the active substances in the serum as *agglutinins*, and believes that to these may be attributed the chief agency in the healing of infectious diseases and in the production of immunity against the same. *Pfeiffer*, on the contrary, denies the occurrence of any swelling of the cell-membrane, and explains the phenomenon as due to an inhibition of development, and designates the active substances, the nature of which is wholly unknown, as *specific paralyzins*. After *Gruber* had demonstrated the peculiar action of the blood-serum of typhoid-fever patients, *Widal* (*Sem. médicale*, Paris, 1896) proposed that this action of the blood-serum on cholera-spirilla and typhoid-bacilli be utilized as a diagnostic aid during the course of an attack of typhoid. The investigations of *C. Fraenkel*, *du Mesnil*, and others have demonstrated that it is possible, during the course of the attack or for a long time (several months) afterward, that the diagnosis of typhoid may be made from the action of the serum upon cultures of typhoid bacilli.

*Metschnikoff*, *Bordet*, and others hold that the chief cause of healing from infectious diseases and of the acquiring of immunity (see § 32) is to be found in the activity of the leucocytes, which, according to their view, supply bactericidal substances to the body-juices and destroy the bacteria by taking them up into their cell-bodies. Phagocytosis, however, plays only a subordinate rôle, since most of the bacteria are destroyed by the cells, only after they have been injured or killed by the bactericidal substances of the blood-serum and the tissue-juices. In many infectious bacteria are indeed taken up by cells, but are not destroyed by them; on the other hand, they may find in the cell-protoplasm a soil favorable to their development.

It has often been assumed that the **fever** occurring in infectious diseases is a protective process favoring the destruction of bacteria; and it is not impossible that in individual cases it may exert such a favorable influence. Thus, for example, it is conceivable that a parasitic micro-organism, growing well at a temperature of 37-38° C., will not thrive at a temperature of 40-41° C., so that high fever-temperatures may hinder its power of reproduction. The conclusion should not, however, be drawn from this that fever is a useful phenomenon which always favors the counter-balancing of pathological disturbances. Even in those cases in which the metabolic processes occurring during the fever exert an injurious influence upon the bacteria, this is not to be taken as proving the usefulness of fever. We can only say that a part of the morbid processes occurring during an infectious fever leads to a formation of decomposition-products which may possess antibacterial or antitoxic properties.

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- See also § 30 and § 32.

## II. The Acquiring of Immunity against Infection and Intoxication. Protection through Inoculation.

§ 32. The acquiring of immunity against a particular infectious disease is a phenomenon whose frequent occurrence has long been known through clinical observations. This fact has been established chiefly by the observation that the great majority of men suffer but one attack of such widespread infections as measles, smallpox, whooping-cough, scarlet fever, and diphtheria, and that after such attack they are spared by the disease, even when they expose themselves under the most varied conditions to the danger of infection with its poison. The knowledge of this fact is very old, and early in the eighteenth century it had led, in the Orient, to attempts to obtain immunity against the natural contagion of smallpox by the inoculation of material from smallpox pustules. In the latter part of the eighteenth century Jenner discovered that the disease known as cowpox—i.e., a milder form of pox, which is either a special variety of disease closely allied to human smallpox or a weaker form of the latter—afforded protection against the true smallpox. As a result of this observation, since the beginning of the year 1796, at first by Jenner himself, afterward by the physicians of all civilized countries,

artificial inoculations of cowpox have been carried out upon millions of human individuals, with the result that through such inoculation a high degree of immunity against the true smallpox has been secured to the inoculated; so that at the present time, in all countries where vaccination is universally practised, the occurrence of widespread epidemics of smallpox, once so frequent, is very rare, and the disease no longer assumes the character of a dangerous pestilence.

The investigations of the last decades with regard to the causes and origin of infectious diseases, which have covered such an extraordinarily broad field, have shown that the **acquiring of immunity against a certain infectious disease through one attack of the given disease** occurs in different infectious diseases, especially in those running an acute course; and represents sometimes a transitory, at other times a permanent peculiarity of the individual concerned, which in pregnant women may be transmitted to the foetus *in utero*. These observations have also shown that the single or repeated **inoculation of attenuated pathogenic bacteria**—that is, of bacteria which on account of their slight virulence produce a disease that, in contrast to the natural infection with bacteria of full virulence, is relatively insignificant, often localized to a limited area—can also confer immunity against the corresponding disease. Further, it has been demonstrated that the **injection of certain chemical substances produced by the bacteria** is sufficient to confer immunity against certain infections.

In explanation of the immunity acquired through an infectious disease or through inoculation, we are at the present time limited to *hypotheses*, yet it cannot be doubted that the last few years have brought great advance in our knowledge of the forces concerned in the production of such immunity, so that we at least know in what direction further researches should be made.

After Pasteur had, in 1880, proved experimentally that chickens could be made immune against chicken-cholera through injections of attenuated chicken-cholera poison, and after it had been established by the investigations of different authors that similar results could be obtained in anthrax, symptomatic anthrax, and swine-erysipelas, it was at first believed that the acquiring of immunity could be explained by the fact that through the inoculation or the first attack of the given infection the food-material in the body had been exhausted (Pasteur, Klebs), so that bacteria entering the body later were unable to find food. This hypothesis, known as the *exhaustion-theory*, cannot be brought into harmony with the observed facts, so that it is now generally abandoned. Also the view of Metschnikoff, that the mesodermal cells become accustomed through the preventive inoculations, to the taking-up of the previously untouched virulent bacteria, and quickly take them up and destroy them after repeated inoculation, can in no wise be regarded as an hypothesis based upon scientific foundations.

According to the facts which have been ascertained by investigations concerning the natural protective powers of the body against infection, and the natural mode of recovery from infections, as well as the experiments made with regard to protective inoculation and the artificial healing of infectious diseases, it is very probable that **acquired immunity is dependent upon the presence of certain chemical substances which are either poisonous for the particular variety of bacteria concerned, or in some manner or other counteract the activity of the product formed by these bacteria** (poison-theory). It is yet an unsettled question whether these

substances are products of the body-cells; further, whether the loss of toxic action of the toxalbumins and toxins formed by the bacteria is due to a destruction of the same, or to the formation of inert combinations of these bodies, or to an immunization of the body-cells against these poisons.

Some light with regard to these questions is given by our present knowledge concerning the different ways in which, not only in experimental animals, but also to a certain extent in man, an immunity against certain infectious diseases may be obtained. Further light is also obtained from experiments concerning the artificial healing of infections which have already begun to develop. As previously stated, it is possible to produce in animals, in harmony with the knowledge obtained through Jenner's cowpox inoculation, **an immunity through the inoculation of attenuated specific disease-germs**; as, for example, in anthrax, symptomatic anthrax, chicken-cholera, diphtheria, swine-erysipelas.

The weakening of the virulence of bacteria may be produced either by the action of high temperatures or chemical agents, or by the action of the air alone; further, it may also be produced by the inoculation of the bacteria into certain animals or through their long-continued cultivation on artificial media. Inoculation is, in general, carried out by injecting subcutaneously first markedly attenuated, then less attenuated, and finally fully virulent bacteria together with their products.

According to the investigations of numerous authors, immunity in animals may also be produced by the **injection of sterilized cultures** in which the bacteria are completely killed—as, for example, against American hog-cholera, symptomatic anthrax, diphtheria, the infectious disease produced experimentally in rabbits by the injection of the *Bacillus pyocyaneus*, and the infection produced in guinea-pigs by cholera-spirilla. It is probable that the immunizing substances are contained in the cell-substance of the bacteria (Brieger, Kitasato, Wassermann).

A third form of artificial immunization, which Raynaud attempted as early as 1877 but was first securely established by Behring in 1890, can be produced by the injection into man or an experimental animal of **blood-serum taken from animals which were previously susceptible, but have been rendered immune by means of inoculations**. The most extensive and at the same time the most successful attempts thus far made have been carried out with *diphtheria* and *tetanus*; that is, in diseases in which intoxication through toxalbumins forms the most striking feature. Moreover, successful experiments with the blood-serum of immunized animals, in the case of cholera, swine-erysipelas, anthrax, typhoid fever, and plague, have been reported.

The specific protection which the blood-serum affords may be secured, not only by injection before infection occurs, but also after infection has already taken place; so that the serum may be designated not only a **protective serum**, but also a **healing serum**. For both protection against and for the cure of a certain infection a *definite amount of serum* is necessary, the precise amount depending, on one hand, upon the severity of the infection, and on the other, upon the activity of the serum itself, which increases with the completeness of the immunization of the originally susceptible animal furnishing the serum. If the serum is not injected until after infection has occurred, the amount of serum must be so much the greater the longer the lapse of time after the beginning of the infection.

In the case of true bacillary *diphtheria*, the injection of curative

diphtheria-serum has now been carried out in thousands of cases, of both severe and light forms; and there is without any doubt a beneficial influence exerted upon the course of the disease, as shown by a rapid improvement of the patient's general condition (rapid establishment of euphoria, fall of fever, improvement in the pulse), as well as by the favorable course pursued by the local disease. In *tetanus* a definite curative action of serum has been demonstrated in the case of experimental animals, guinea-pigs, and mice; but the results in man have not yet been fully determined.

The blood-serum of immunized animals exerts its beneficial action, without doubt, through the presence of a *counter-poison*, an **antitoxin**, which neutralizes the poisons produced by the bacteria. In the case of the patients treated by a given antitoxin, there is produced a **poison-immunity** against the corresponding bacterial poison—as, for example, against the poison produced by the diphtheria bacilli, in those patients injected with diphtheria-antitoxin—and this immunity is to be ascribed to the presence of a definite amount of antitoxin in the blood.

The chemical nature of the antitoxins, whose occurrence in numerous infections and intoxications (diphtheria, tetanus, pneumonia, snake-poison, poisoning with ricin, abrin) has been demonstrated, is not known. Their mode of action may be explained either by the assumption that they destroy the specific bacterial poisons (Behring), or that they only render the tissues insusceptible to the action of the latter (Buchner, Tizzoni, and others), or finally, that they form in the blood and tissue-juices a chemical combination with the toxins which is not harmful to the cells (Ehrlich).

Besides the antitoxins, the blood-serum of immunized animals or human beings may also contain **bactericidal substances**, which injure or kill the bacteria themselves; and this is said to occur especially in cholera and typhoid infections (R. Pfeiffer, Gruber, Durham) and in infections with the pneumococcus (Emmerich). Emmerich assumes that these substances are of the nature of bacteriolytic enzymes.

The **origin of the immunizing substances** in the blood is not yet known, and we are at present confined to hypotheses. It is probable that the bactericidal substances have not the same genesis as the antitoxic.

In the case of immunization by means of attenuated cultures or by sterilized chemical bacterial products, the antitoxic substance is produced as a new body within the organism, and this process has been designated **active immunization** (Ehrlich); in the case of the injection of immunizing serum the antitoxin already formed is introduced from without, and this may be spoken of as **passive immunization**. It is probable that in the last case no new-formation of antitoxin occurs after the injection.

It is most probable that *antitoxins are formed by the cells of the infected individual*, according to Ehrlich's view (see below) by those cells which are especially influenced by the toxin (in tetanus, for example, by the nerve-cells). The antitoxin is probably nothing more than an element of the cell-protoplasm, which has an especial relation to the given toxin, and, thrown off from the cell and dissolved in the blood, combines with the toxin to form a harmless body. The fact that the substance producing the immunity is active only against the given infection may be explained by the assumption that the individual toxins or toxalbumins possess the affinity, which is necessary to the production of an intoxica-

tion, only for certain portions of certain cells; and that, therefore, following the intoxication, only the immunizing substances for the particular poison are produced by the cells and given to the blood.

By many writers it is believed that the anti-bodies, both bactericidal substances and antitoxins, are formed by the bacteria themselves, or that the bacterial cells furnish the material for these, in cultures as well as within an infected body (Buchner).

For the foundation researches in regard to inoculation with attenuated cultures of bacilli cultivated outside of the body, we are indebted to *Pasteur*, who, in 1880, demonstrated the fact that chickens could be immunized against chicken-cholera through the inoculation of cultures of *chicken-cholera bacilli*, that had been weakened through long exposure to the air.

Since that time numerous experiments have been carried out with other forms of bacteria, especially with attenuated cultures of the bacilli of anthrax and symptomatic anthrax. The best results have been obtained from inoculations against the symptomatic anthrax of cattle. Less favorable are the results in inoculations against anthrax, in that some of the animals die from the effects of the protective inoculation, while others are not rendered absolutely immune against a new anthrax infection.

Sheep and cattle may be made immune against *anthrax*; most expediently (*Koch*) by first inoculating them with attenuated cultures of anthrax-bacilli, which will kill mice but not guinea-pigs, and then with those which will kill guinea-pigs but not strong rabbits.

As vaccine against *symptomatic anthrax*, there may be used cultures of the bacillus attenuated through heat or such chemical agents as sublimate solutions, thymol, eucalyptol, and silver nitrate; and by such inoculations cattle may be rendered immune. At the present time heat (*Hess, Kitt*) is most commonly used in the preparation of the vaccine. The infected muscle of an animal dying with symptomatic anthrax is chopped fine, triturated with one-half its weight of water, and pressed through a piece of linen cloth. Finally, the fluid is again filtered through a moistened piece of fine linen. The virulent material is then spread in thin layers upon glass plates or flat dishes, and transferred to a dry chamber at a temperature of 32-35° C. When thoroughly dry the virus is scraped off and removed in the form of powder. When it is desired to give inoculations, the virus is triturated with double its weight of water and the fluid evaporated in a thermostat. By raising the temperature to 100° C. for six hours a weak vaccine is obtained; at a temperature of 85° C. for six hours a stronger one. For the immunization of cattle, about 0.5 gm. of the weaker virus in a dilute water solution is injected into the subcutaneous tissue of the animal's tail, and after eight to twelve days the stronger solution is similarly injected.

According to observations of *Chaureau* and others, protective inoculations may also be made by the injection of virulent bacteria in very small quantities, or in such a manner that the life of the animal shall not be endangered. In the case of symptomatic anthrax this may be accomplished by the injection of very small doses into the extremity of the animal's tail; such injections not causing a fatal illness, but only a local disturbance.

According to *Afanassieff*, it is possible to render animals immune by inoculating the granulating surface of a wound with a virulent culture.

Cattle may also be immunized against *contagious pleuropneumonia* (*Schütz*) by injecting the tissue-juices from the lung of an animal dying from this disease into the tip of the tail. There is produced in this way a circumscribed inflammation, or, at least, one which is confined to the tail; after recovery from which the animal is immune to both natural and artificial infection with this disease.

Hogs may be rendered immune against inoculation with virulent bacilli of *swine-erysipelas* (*Pasteur*), by using, as vaccine, cultures attenuated by successive inoculations in rabbits. According to *Emmerich*, rabbits may also be made immune against the bacilli of swine-erysipelas through the injection into the ear-vein of a small quantity of a virulent bouillon-culture diluted with fifty times its volume of water.

Animals susceptible to *diphtheria* may be rendered immune against this disease, according to *Behring*, by the injection of cultures of diphtheria-bacilli which have been weakened in virulence by exposure for sixteen hours to iodine trichloride (1:500). Two cubic centimetres of such a culture is injected into the peritoneal cavity; after three weeks this injection is repeated with a diphtheria-culture (0.2 c.c.) which has been washed four days in bouillon containing iodine trichloride (1:5,500). After this, fully-virulent cultures are injected in increasing doses.

Rabbits may be rendered immune against pneumococci (*Emmerich*) by injections



of 0.3 c.c. of a strongly-virulent bouillon-culture which has been diluted five thousand times, followed later by injections of bouillon-cultures of full virulence.

Protective inoculations against *rabies* were first carried out in cases resulting from bites by rabid animals, particularly in France (Pasteur Institute), Russia, and Italy. As inoculation-material, the spinal cord from rabbits which have been infected with rabies is used after it has been dried in dry air at a temperature of 23-25° C.; the virulence of the cord being gradually lost after about fifteen days of the drying-process. According to *Protopopoff*, it is the temperature, and not the drying (*Pasteur*), which lessens the virulence. According to *Marx*, the micro-organisms of rabies have already been weakened in the body of the rabbit. Small portions of a rabbit's cord thus weakened in virulence are triturated in sterilized chicken-broth and injected subcutaneously into the bitten individual; at first pieces of cord greatly reduced in virulence are used, then those of gradually increasing virulence. According to the view held by *Pasteur*, the spinal cord contains both the microbes of the disease and the specific poison formed by them; if the latter spreads through the body more rapidly than the microbes, it confers an immunity against a subsequent spread of the microbes, and affords protection to the nervous system in particular. In order to confer immunity it is, therefore, necessary to introduce as large a quantity as possible of the chemical poison. According to the reports of the Institutes in which the Pasteur inoculations against hydrophobia have been carried out, it must be acknowledged that these inoculations have been successful in preventing cases of hydrophobia.

Immunity against *cholera* may be produced, in both man and animals (*Haffkine*, *Pfeiffer*, *Kolle*, *Voges*, and others), by the injection of sterilized or attenuated cultures of cholera-spirilla; this immunity (which is of short duration) depends upon the formation of specific bactericidal anti-bodies in the blood (see *Voges*, l. c.). On the other hand, we do not yet possess a specific remedy by which the life of any animal or man infected with cholera may be saved.

Immunity against *typhoid fever* may be secured in man by the subcutaneous injection of sterilized cultures of typhoid-bacilli (*Pfeiffer*, *Kolle*); and the establishment of the immunity may be recognized by the fact that the blood-serum of the individual so inoculated is found, after a few days, to contain bactericidal substances. Attempts at immunization in cases already ill with typhoid (*Brieger*, *Wassermann*, *C. Praenkel*) have up to the present time been unsuccessful.

According to the reports published by *Koch* (*British Medical Journal*, 1897; *Deut. med. Woch.*, 1897, No. 16; *Centralblatt f. Bakt.*, xxi., p. 526) of the investigations which were carried out during the winter of 1896-1897 with regard to the cattle-plague in Cape Colony, cattle may be immunized against "*Rinderpest*" by subcutaneous injections of 10 c.c. of the bile taken from animals dying of the disease; the condition of immunity becoming established at the latest by the tenth day. According to the report of Professor Winkler ("*Landwirthschaftl. Bezirks-Verein Giessen*," August, 1900) hogs and cattle may be immunized against *mouth-and-hoof disease* through feeding with milk of animals which are affected by the disease or have recently recovered from it.

In the year 1890 *Koch* made the discovery that cultures of tubercle-bacilli contain a toxin, "*tuberculin*," which, when injected into tuberculous individuals, causes a rise of temperature and to some extent local inflammatory changes in the neighborhood of tuberculous foci. It was at first hoped that in tuberculin a remedy for tuberculosis had been found, but the many trials made with it upon human beings and animals have shown that it indeed produces after repeated injections an immunity against the toxic action of tuberculin but does not hinder the multiplication of tubercle-bacilli and the consequent spread of the disease. Further, the local inflammation caused by the tuberculin leads to favorable results only under special conditions, but, on the other hand, often causes actual harm (through the metastasis of bacilli). Nevertheless, *Koch's* discovery has proved of great importance. In the first place, it is of practical value in the diagnosis of tuberculosis, in that tuberculin injections do not excite fever in normal individuals. Inoculations for diagnostic purposes are now used very extensively in cases of suspected tuberculosis in domestic animals. Moreover, the reports published by *Koch* gave a great stimulus to further investigations with regard to immunization by means of inoculation with bacterial toxins; and these investigations have led to the discovery of the antitoxins of diphtheria, tetanus, cholera, and typhoid fever.

*Maragliano* has recently attempted to obtain a healing-serum against tuberculosis by the inoculation of experimental animals (donkey, dog, horse) with the toxins derived from cultures of tubercle-bacilli. The observations thus far made do not warrant the conclusion that this serum possesses the power to cure tuberculosis in the human being. In 1897, *Koch* ("*Ueber neue Tuberculinprparate*," *Deut. med. Woch.*, 1897) succeeded in obtaining from highly virulent cultures of tubercle-bacilli a substance which he claims is able to immunize against all of the constituents of the tubercle-bacillus. To obtain this substance young cultures of tubercle-bacilli are dried in a

vacuum-exsiccator and then triturated. The product obtained by trituration is mixed with distilled water and centrifugated. The active substance is contained in the muddy precipitate thus obtained (designated by Koch as T. R.). This is again dried and triturated, dissolved in water to which twenty per cent of glycerin is added for the purpose of preservation. (The preparation is manufactured by Meister, Lucius, and Brünning, at Höchst-on-the-Main, Germany.) The fluid preparation contains 10 mgm. of solid substance in every cubic centimetre, and when it is to be used should be diluted with physiological salt solution. Through the use of large doses animals are said to become immunized in from two to three weeks. In the treatment of tuberculosis in man the dose should begin at  $\frac{1}{100}$  mgm. and gradually be increased up to 20 mgm., the injections being given every other day. According to the observations so far published, the T. R. preparation does not appear to exert a curative action upon tuberculosis in man.

Very recently Yabé has reported that there may be obtained from cultures of tubercle-bacilli a substance (tuberculo-bactericidin) which has a bactericidal action; but no definite conclusions can be drawn from the published results of his experiments.

The blood-serum treatment of diphtheria, i.e., the employment of the antitoxins contained in the blood of an animal immunized against diphtheria as a means of curing that disease when it is already contracted, or as a protection against such infection, is a discovery which we owe to Behring. The favorable effects of the method discovered and proved by him through experimental investigations have been confirmed by thousands of observations. In the treatment of diphtheria patients a large quantity of the serum (one thousand immunizing units) is usually injected at one time beneath the skin of the thigh.

The term "normal serum"—i.e., a serum having the value of one immunization unit—is used by Behring to designate a serum which, when mixed with a quantity of diphtheria poison equal to ten times the minimal fatal dose and then injected in the amount of 0.1 c.c. into a guinea-pig of from 200 to 300 gm. weight, will surely protect that animal from diphtheria. Sheep and horses are especially adapted for the preparation of the serum. It is prepared and sold in doses of from five hundred to three thousand immunization units.

If culture-filtrates of the *tetanus-bacillus* are weakened by the action of chemical agents (iodine trichloride or iodine combined with potassium iodide), it is possible through repeated injections of such filtrates of increasing virulence to produce immunity in animals against tetanus (Kitasato, Behring, Tizzoni, Buchner). The blood of such immunized animals contains an antitoxin which affords a sure protection to experimental animals against tetanus. The antitoxin treatment of human beings suffering from tetanus has not given satisfactory results (see Kohler and Schlesinger, l.c.), not even in cases of relatively early injection of the antitoxin, though it appears to be effective if administered before the appearance of the tetanus.

Susceptible animals and human beings may be immunized against bubonic plague by means of sterilized cultures of the pest-bacillus (Yersin, Haffkine, Kolle); and it appears that in the blood-serum of immunized animals (the horse, for example) there are present anti-bodies which render the serum utilizable for both protective and curative purposes.

Animals may be made immune against snake-poisons by means of inoculations of very small doses of such poison continued for some length of time (Culmette, Tschistovitch); and the blood-serum of such immunized animals is also found to possess an antitoxic action against the given poison, so that it may be used as a healing-serum. In Brazil, Mexico, Africa, etc., various methods involving the use of snake-poison itself are employed for the immunization of individuals against a snake-bite, or for curing them after they have been bitten (drinking of the secretions of the poison-glands, rubbing of the diluted poison into small wounds of the skin, etc.) (Brenning).

According to the investigations by Ehrlich, mice may be made immune against ricin, to which they are extremely susceptible, by mixing very small doses of ricin with their food and then afterward injecting additional small doses subcutaneously. The appearance of the immunity occurs on the sixth day after the administration of the ricin, so that upon this day the animal can withstand a dose thirteen times as great as at the beginning. Through continued systematic inoculations the animal becomes immune to a dose eight hundredfold as strong. The immunity is produced by an antitoxic body, antiricin, which neutralizes the poisonous action of ricin.

Though not giving definite information regarding the processes which lead to the acquiring of immunity, the hypotheses of Ehrlich are well qualified to give an explanation for the observed processes, and possibly correspond to the actual conditions.

According to Ehrlich's view, only those substances are poisons which possess a chemical relationship with some constituent of the body, and, through combination with the same, cause an injurious effect recognizable clinically (toxophorous relationship). The natural immunity of an individual can, therefore, depend upon the fact

that the poison finds in the immune body no element with which it can effect a chemical combination, or that the body-element so combined suffers no injury in a clinical sense.

*Antitoxic immunity* can be produced either through the introduction of weak doses of toxin or through the injection of a serum containing antitoxin. The first is an *active immunization*, in that the organism itself forms the toxin; the second is a *passive immunization*, in that the antitoxin is injected already prepared, so that immunity is at once produced. The active immunity can persist for years; the passive, on the contrary, is usually lost after a few weeks or months at the farthest.

An *antitoxin* is a cell-product which arises as a result of disease of the organism, and is given off into the blood. In passive immunity the body-cells are not active, the injected antitoxin is sufficient to neutralize the toxin. Antiricin, when added in a certain amount to a ricin-solution, lowers the power of ricin to agglutinate red blood-cells in undiluted or in diluted blood. The same mixture also renders ricin harmless for animals.

The toxin is not destroyed by the antitoxin. If snake-venom be mixed with the antitoxin (*Calmette*), so that the mixture is harmless for animals, and if the antitoxin, which is the more sensitive to heat, be destroyed by warming the mixture to 68° C., this again becomes poisonous. A similar fact has been demonstrated in the case of the toxin and antitoxin of the *Bacillus pyocyaneus* (*Wassermann*).

The toxin becomes harmless through its union with the antitoxin to form a harmless chemical combination.

The antitoxin produced in the body in cases of active immunization does not arise from the toxin. The poisons forming antitoxins show, in contrast to other poisons, certain peculiarities, which consist essentially in that they possess chemical affinities for certain elements of the cells, the "side-chains." The complicated protoplasmic bodies possess (as does the benzol ring), besides the "governing nucleus" or "central group," a great variety of such "side-chains." It may be assumed that certain substances influence certain side-chains, enter into chemical combination with the same, and through the medium of these side-chains affect the central chain and thereby damage the vital capacity of the cells. If thereby the life of the cell and with this its capacity for compensation are not damaged, if there occurs only a functional disturbance but no definite injury to the central group, the cells may restore the side-chains, even build up new ones in excess, which may be thrown off and given to the blood, the side-chains thus given off constituting the antitoxin. The antitoxin is therefore no new substance, but one occurring normally, which under certain conditions is produced in an increased amount, given over to the blood, and in the circulation combines the toxins entering the blood into harmless bodies, and thus prevents the action of the toxins upon the cells. As expressed in the words of *Behring*: "The same substance in the living body, which lying in the cells is the hypothetical essential to an intoxication, becomes the cause of healing when it is found in the blood."

Ehrlich's hypothesis is without doubt well adapted to explain the phenomena of antitoxic immunity. It has been supported by recent observations of different authors. *Wassermann* has found that the substance of the central nervous system which is especially affected in tetanus is able to combine the tetanus poison after the manner of an antitoxin and to render it harmless. Tetanus-poison, when mixed with the triturated brain-substance of a healthy guinea-pig, becomes so weakened that guinea-pigs can bear without harm a dose equal to ten times the fatal dose.

*Ransom* and *Marie* obtained the same results. The former also showed that the poison of tetanus, when injected in fatal doses into doves, could be demonstrated in all organs with the exception of the central nervous system, in which it had entered into combination with chemical elements.

Ehrlich's hypothesis has been attacked especially by *Roux*, *Borrel*, *Metchnikoff*, and *Knorr*; but their observations may be brought into harmony with the hypothesis (see *Weigert*, l.c.).

*Bactericidal immunity* depends chiefly upon the presence of newly-formed immune-bodies, which are able to withstand heating to 56–60° C., and, wholly specific in their action, are directed against the variety of bacteria corresponding to the immunization (*R. Pfeiffer* and others).

These immune bodies exert their influence under certain conditions; according to the view held by *Bordet*, *Ehrlich* and *Morgeroth*, *von Dungern*, and *Wassermann*, their activity is dependent upon the addition of a thermolabile ferment-like substance, which is found even in normal blood-serum (according to *Bordet*, the *alexin* of *Buchner*, the *adjuvant* or *complement* of *Ehrlich*).

Of exactly the same composition as the bactericidal are also the corresponding *globulicidal immune-sera* (specific *hæmolysins*), which are produced by the introduction of blood into the body of an animal of a different species (*Bordet*, *von Dungern*, *Land-*

steiner); in this case also the action of the immune-serum depends upon the presence of two substances—the *immune-body* produced through the immunization, and the *complement* already present in normal blood-serum. *Ehrlich* and *Morgenroth* have further explained the mechanism of these processes by means of experiments at combining these substances. The immune-body shows great specific affinity for the corresponding erythrocytes; it combines with these even at 0° C., and, thus separated from the complement remaining in the serum, is nevertheless not able to dissolve the blood-corpuscles by itself. The complement will not be combined by the blood-cells without the immune-body. If the latter is present at the same time, the complement is taken at higher temperatures out of the serum by the erythrocytes, whereby the solution of the red cells takes place.

*Ehrlich* and *Morgenroth* explain this by the assumption that the *complement*, which represents the active substance proper, is carried over to the erythrocytes by means of the *immune-body*. This conclusion accords very well with the *side-chain* theory. The *immune-body* is a *side-chain*, which, produced in excess, is thrown off into the blood. To the production of the immune-body a certain molecule-group of the erythrocytes gives occasion, and this group is indeed the same which in hæmolytic enters into combination with the immune-body (*von Dungern*). The immune-bodies are distinguished from the analogous antitoxins only in that they are more complex; they possess, besides the haptophorous complex which has a chemical affinity for the corresponding complex of the proper erythrocytes, yet another haptophorous group, which is able to combine the complement. Corresponding complementophile side-chains may also be demonstrated in the organs; the most varied kinds of tissue-cells are able to take out the complement from the blood-serum (*von Dungern*).

In the reaction of immunity the immune-bodies are produced exclusively; the complement is not increased beyond the amount required (*von Dungern*).

The property of many normal sera to dissolve foreign blood-cells is dependent, according to the investigations of *Ehrlich* and *Morgenroth*, exactly as in the case of the immune-sera, upon the joint action of two substances. Many times there can also be demonstrated, besides the complement, an "intermediary body" corresponding to the immune-body (the complement is therefore not wholly to be identified as *Buchner's alexin*, which embraces both substances).

In an analogous manner to that produced against bacteria and red blood-cells, a reaction of immunity may occur against other cells when introduced into a strange organism—for example, against ciliated epithelial cells (*von Dungern*), against spermatozoa (*Landsteiner*, *Metschnikoff*, *Moxter*), against leucocytes (*Metschnikoff* and others). The immune-sera obtained in this manner act, in so far as they have been studied (*von Dungern*, *Moxter*), according to the same mechanism as the hæmolytic and bactericidal.

The reaction of the animal organism, which hinders or makes impossible the life of cells foreign to it, is manifested not only upon bacteria but upon all possible forms of life foreign to it. According to the investigations of *Ehrlich* and *Morgenroth*, the same reaction may occur even against blood-cells of the same species. After intraperitoneal injection of laked blood of the same species, the blood-serum of a given species acquires the power to dissolve the red blood-cells of another individual of the same species (isolytic). An autolysis has, on the other hand, not yet been observed. The latter could indeed not exist in the blood; it would be combined with the corresponding side-chains of the cells (receptors) and occasion the production of an antiautolysis.

The acquired specific immunity against the causes of infection is, therefore, to be referred to the general law of the formation of anti-bodies.

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*(Hæmolysins; Immune-sera against Cells.)*

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## CHAPTER IV.

### Disturbances in the Circulation of the Blood and of the Lymph.

#### I. General Disturbances of the Circulation Dependent upon Changes in the Function of the Heart, Changes in the General Vascular Resistance and Changes in the Mass of the Blood.

§ 33. The mass of blood is kept constantly in motion by means of the rhythmical contractions of the auricles and ventricles of the heart. The blood, as it is driven into the elastic tube of the aorta toward the periphery of the body, meets a significant degree of resistance, which is caused by the friction in the innumerable divisions and subdivisions of the arterial system. This resistance occasions a relatively high pressure throughout the entire arterial system, which in the human femoral artery equals that of about 120 mm. of mercury. After passing through the capillaries the blood arrives in the veins with very little velocity, and stands in the veins under a very slight pressure, which varies according to the location of the vein, and is greatest where a high column of blood rests upon the lumen of the vein. In the great venous trunks in the neighborhood of the thorax the pressure is usually negative, especially during inspiration, as the thorax during this stage of respiration aspirates the blood from the veins lying outside of the chest. Only during forced expiration does the positive pressure in the veins rise somewhat higher.

Assuming the mass of the blood to be constant, the degree of pressure *within the aorta*, at any given moment, is dependent upon the work of the heart and the resistance in the arterial system. The latter in turn is dependent upon the variations in the total diameter of the combined cross-sections of the blood-vessels, due to the elasticity and contractility of the arteries. In the major circulation the arterial tone is very pronounced; in the lesser circulation it is slight, the blood-pressure in the pulmonary artery being only from one-third to two-fifths that in the aorta. Both the heart and the arteries are under the influence of the nervous system, which regulates their activity.

The activity of the heart consists in rhythmical contractions of its musculature; and its normal efficiency presupposes that the heart-muscle, and also the cardiac ganglia, are sound. Every disease of the heart, therefore, in so far as it diminishes the contractile capacity of the heart-muscle and lessens the activity of the ganglion-cells, and in so far as a lessened functional activity of certain parts of the cardiac muscle is not compensated by an increased activity of other parts, will **diminish the functional capacity of the heart**.

In many cases in which the functional capacity of the heart-muscle is impaired, certain anatomical changes, such as fatty degeneration and necrosis of its cells, can be demonstrated; in other cases no anatomical



changes can be made out, especially in those cases in which the diminution of working-capacity follows the exhaustion caused by excessive overexertion. This may occur when the heart is forced to work for some time only slightly above the normal, but under unfavorable conditions, as, for example, in cases of elevation of the body-temperature; as well as in cases when for a short period it is overworked to an excessive degree. Under certain conditions disturbances of nutrition and intoxications, such as occur in the infectious fevers, as well as a sudden diminution in blood-supply from the obstruction of a coronary artery, may cause an insufficiency of the heart within so short a time that the heart-muscle presents no recognizable anatomical lesion. The work of the heart may also be made difficult at times through the formation of adhesions between the epicardium and pericardium, and between the latter and the contiguous pleura, in consequence of which the contractions of the heart are hindered.

Through the collection of fluid in the pericardial sac in the course of certain diseases, further, through marked deformities of the thorax causing an abnormal smallness of the thoracic cavity, and through a high position of the diaphragm, the diastolic dilatation of the heart and the free afflux of blood from the veins may be hindered to such an extent that the ventricles receive too little blood. If, following pathological processes in the heart-valves, there result rents or distortions of the flaps or adhesions between them, or if in case of dilatations of the heart and the valvular orifices the valve-flaps become relatively too short, there may arise those conditions of the auricular and ventricular orifices known as insufficiency and stenosis. The former condition is characterized by a failure of a valve to close completely during the diastole of the auricle or ventricle lying behind the given valve; the second condition, by the fact that during the contraction of the auricle or ventricle the valvular orifice does not suffice for the passage of the blood through the opening. The effect of a stenosis is that of opposing additional obstacles to the out-flow of the blood during systole. In aortic and pulmonary insufficiency the blood regurgitates, during the ventricular diastole, back from the great vessels into the ventricles; in mitral and tricuspid insufficiency the systole of the ventricle causes a regurgitation into the corresponding auricle.

Finally, there are not infrequently formed in the heart masses of coagula, which under certain conditions—in case they lie near the orifices—may on the one hand interfere with the proper closing of the valves, or on the other cause a narrowing of the ostium.

As the result of all the above-mentioned pathological conditions, the **efficiency of the heart's function is impaired**, so that in a given time too little blood passes into the arterial system, the aortic pressure consequently falls, and the velocity of the blood-current is diminished; while in the venous system the blood collects more and more, and the venous pressure rises. There is consequently an *inadequate filling of the arteries* throughout the entire body, varying, indeed, according to the degree of contraction maintained in individual arterial systems, while both veins and capillaries are, on the other hand, overfilled with blood. There develops, therefore, a condition of general **venous hyperæmia**, which in some parts may become so marked that the tissue, because of the engorgement of the capillaries with venous blood, acquires a *blue-red, cyanotic appearance*. When the difference in pressure between the arterial and venous systems becomes reduced to a certain minimum, the circula-

tion comes to a standstill, while the right side of the heart becomes greatly distended with blood.

Should the contractions of the heart from any cause become weak and imperfect, the pulse-wave also becomes small. If the rate of the heart-beat becomes diminished in frequency, the arterial system empties itself to a greater extent than normally during the pause between the systoles.

If the impairment of cardiac efficiency involves the left heart essentially, as is the case, for instance, in valvular disease of the left side, the disturbance of circulation is manifest first in the systemic arteries, as well as in the pulmonary vessels.

In stenosis of the aortic valves, the arteries, if the heart's action remain unchanged, fill but slowly and incompletely (*pulsus tardus*). In aortic insufficiency a normal or even an increased amount of blood is thrown into the arteries during systole (*pulsus celer*), but a part of this flows back again during diastole. In both cases the left ventricle becomes more and more distended, the emptying of the left auricle is hindered, its cavity also becomes dilated, and finally the blood is backed up in the pulmonary veins. Owing, however, to the low pressure in the pulmonary circulation, the blood is readily dammed back upon the right ventricle, and the blood stasis may finally extend beyond this into the right auricle and into the systemic veins.

Valvular lesions at the mitral orifice produce similar effects upon those portions of the circulatory apparatus lying behind the left auricle, as in such cases there is produced also a condition of pulmonary stasis, with a rise of pressure in the pulmonary arteries and veins; while the left ventricle either receives too little blood (stenosis) or during its contraction drives a portion back into the auricle (insufficiency).

In valvular lesions of the orifices of the right heart the damming back of the blood is limited to the veins of the systemic circulation, while in the pulmonary circulation both pressure and velocity are diminished. Further, the pressure in the aorta also falls, since the left side of the heart receives too little blood.

The damming back of the blood in the great systemic veins may manifest itself by *venous pulsations* in the neighborhood of the thorax, inasmuch as retrograde waves of pressure proceeding from the heart may pass through the veins toward the capillaries, distending the veins to such an extent that the venous valves, particularly those of the jugular bulb, are rendered inadequate. The essential condition of the transmission of the venous pulsation is the insufficiency of the venous valves. In the case of imperfect function of the valve in the jugular bulb, a slight pulsation may be observed even during normal action of the heart; but when the veins are distended, and particularly in the case of tricuspid insufficiency, the pulsation becomes much stronger and extends further toward the periphery. If the tricuspid is adequate the venous pulsation (presystolic) is only the expression of the rhythmical occurrence of a hindrance to the outflow of blood from the veins (negative or normal venous pulse). In tricuspid insufficiency the contraction of the right ventricle forces blood back through the tricuspid opening into the right auricle and into the veins beyond, giving rise to a systolic venous pulsation (positive venous pulse).

If in a heart affected with a valvular lesion the chambers lying behind the lesion become distended with blood, the muscular walls of these chambers, in case they are otherwise normal, may by an increased activity **compensate for the valvular lesion** within certain limits. In the

course of time there results an increase in the volume of the heart-muscle, a **hypertrophy of the heart-muscle**, which enables the heart to carry on its increased work for an indefinite period. Such compensation frequently becomes inadequate, with the result that the aortic pressure is permanently lowered, while the venous pressure, on the other hand, is abnormally high. There is, at the same time, the danger that the heart-muscle may in time become exhausted, or that a very slight illness may render the heart insufficient. Thus, for example, a prolonged quickening of the heart's rate, by shortening the diastolic periods of rest, may cause cardiac exhaustion and insufficiency. Arrest of the heart's action finally follows, with great accumulation of blood in the heart, since the heart is no longer able to drive onward the mass of blood entering it.

An **increase of the heart's action**—that is, an increase in the frequency of the heart's contractions, these at the same time remaining strong and complete—causes an increase in arterial pressure and an increased velocity of the blood-current. When increased demands are frequently made upon the left side of the heart—as frequently happens in heavy bodily labor, conditions of luxurious living, abnormal irritability of the cardiac nerves, etc.—the left ventricle may become hypertrophic and act permanently with greater force. Inasmuch as the quickening of the blood-stream causes the right heart to receive a greater amount of blood during diastole, a hypertrophy of the right ventricle is usually found in connection with the hypertrophy of the left ventricle.

**Lessening of the mass of blood or general anæmia** from the loss of blood leads temporarily to a fall of pressure in the aorta; but if the loss of blood was not excessive, the blood-pressure rises again, as the vessels adapt themselves to the changed conditions, and, as the result of the stimulation of the vasomotor centre through local anæmia, show a greater degree of contraction. Under normal conditions the mass of blood is quickly increased through the absorption of fluids, and later by a regeneration of the blood. Similarly, in **anhydræmia**—i.e., a diminution of the water of the blood—the arterial pressure is lowered and the blood-current slowed. After severe hemorrhages the arterial pressure is lowered for a greater length of time, the circulation is slowed, and the pulse, because of the lessened stimulation of the vagus-centre (Cohnheim), is frequent and small.

In the case of lasting diminution of the blood-mass—i.e., the condition known as **chronic anæmia**, which occurs under varying conditions—the vascular system is imperfectly filled, the blood-pressure lowered, and the blood-current slowed. Both heart and blood-vessels adapt themselves to the new conditions and become diminished in volume. In the case of a marked deficiency of hæmoglobin, degenerations of the heart-muscle, particularly fatty degeneration, frequently occur.

**Increase in the mass of the blood**, through the injection of blood or salt-solution into the blood-vessels, is followed in animals by only a temporary increase in pressure and in the velocity of the blood-current. A return to the normal is brought about, partly by the dilatation of a part of the vascular system, particularly in the abdomen, and partly through the elimination of the surplus from the vessels. If the mass of blood, as the result of some especial predisposition or of high living, comes to stand in an abnormally high proportion to the body-weight, if there exists a **permanent plethora**, the pressure in the aorta becomes permanently raised, the work of the heart is permanently increased, and there develops a corresponding *hypertrophy of the heart*.

§ 34. **Increase of the general vascular resistance** may occur in either the greater or the lesser circulation, and results in an increased pressure behind the point of increased resistance, and a diminished pressure beyond it.

In the **systemic circulation** the hindrance may lie either in the main vessel, the aorta, or in the arterial branches, whose degree of contraction maintains and governs the normal pressure in the aorta. Vascular contraction involving a great number of arteries and their branches, and sufficiently well marked to increase the blood-pressure, is generally a temporary phenomenon, passing off with the relaxation of the arterial tension. Nevertheless, a permanent increase in the aortic pressure with consequent hypertrophy of the left ventricle does occur; and this cannot be explained otherwise than as the result of the contraction of the lumen of the smaller arteries. Transitory arterial contraction and increase of pressure occur particularly through an increase of the amount of carbonic acid contained in the blood. A permanent increase of aortic pressure is, on the other hand, a result of chronic diseases of the kidney, in which the secreting parenchyma is destroyed. Inasmuch as the portion of the vascular system which is thus cut off is much too small to cause such an increase of pressure throughout the whole aortic system, since the vessels leading to other organs might become correspondingly dilated, it must be assumed that in the case of contracted kidney some other hindrance to the circulation occurs throughout more extensive vascular areas. This hindrance would most naturally be sought in the apparatus which normally serves to keep the aortic pressure at its proper height, namely, in the smaller arteries of the body. Whether the condition is caused by nervous stimuli arising in the kidney, or by the action of retained urinary substances upon the vasomotor centres or directly upon the vessel-walls, or whether the heart is excited by nervous stimuli to increased action, we are not at present able to say.

Increase of resistance in the aorta may result from stenosis of this vessel, as occurs in rare cases at the isthmus, or from congenital narrowings of the whole aorta, large aortic thrombi, or from extensive disease of the vessel-wall, in consequence of which the intima is rough and nodular, the entire vessel rigid, inelastic, and unyielding; or, finally, from a general dilatation of the vessel, whereby eddies are formed in the blood-stream.

**Lowering of the total resistance in the systemic circulation** is possible through the relaxation of the tone of a large part of the arteries, and this event may happen when the vasomotor centre is paralyzed, or when the cervical cord is divided or partly destroyed through any other process. Since the blood, in this case, flows abnormally quickly from the arteries into the veins, the difference in blood-pressure between the arteries and veins is lessened, the current becomes slower, the heart receives too little blood during diastole, and, finally, the circulation may come to a standstill.

**Increase of the resistance in the pulmonary circulation** occurs most frequently as the result of disease of the lungs and pleura. Adhesions of the pleura, as well as spinal curvatures, which hinder the expansion of the lungs and their change of volume during inspiration, thereby depriving the circulation of an efficient aid, may cause such increase of pulmonary resistance. Of great influence, moreover, are such affections of the lung as idiopathic emphysema, retractions and indurations of the lung, and destruction of lung-tissue—all of which lead to the obliteration

tion of a portion of the pulmonary capillaries; further, compression of the lung through pleural exudate; and, finally, compression of the pulmonary arteries by aortic aneurism or by tumors.

If the hindrance is only slight, the blood may make for itself a new passage to the left heart without any increase of pressure; the rate of the current in the blood-vessels which are unobstructed alone being increased. Greater obstacles cause an increase of pressure in the pulmonary artery and the right heart, and if the condition persists for some time the right ventricle through increased exertion may become hypertrophic. This can occur, however, only when the heart-muscle is adequately nourished and when the mass of the blood is not diminished to correspond to the diminution of the area of the pulmonary vessels. If the right heart is not able to overcome the obstacles in the pulmonary circulation, the blood is dammed back upon the right heart, and eventually upon the systemic veins.

An increase of the pressure in the right side of the thorax hinders the entrance of the venous blood into the right heart, and causes an accumulation of blood in the systemic veins. A sudden increase of pressure may cause a retrograde flow of blood into the neighboring veins.

According to the investigations of *Romberg, Pässler, Bruhns, and Müller*, pneumococci, diphtheria-bacilli, and the *Bacillus pyocyaneus* injure the circulatory apparatus of the rabbit, in that they cause paralysis of the vasomotor centres in the medulla. This paralysis leads to a diminution of the arterial blood-pressure and to a change in the distribution of the blood. The splanchnic vessels become overfilled, the vessels of the brain, skin, and the muscles become empty. The heart is not concerned in this disturbance of the circulation. In general, it is affected secondarily as a result of the deficient flow of blood due to the vasomotor paralysis. A central paralysis of the vasomotors is also responsible for the circulatory disturbances occurring in the acute infections; and is the chief cause of the failure of the circulation.

The observation that hypertrophy of the heart follows different diseases of the kidneys has been interpreted in various ways. Some writers seek the cause in an increase of the volume of the blood (*Traube, Bamberger*), others (*Senator, Ewald*) believe it to be due to the changed character of the blood, while others (*Gull and Sutton*) ascribe it to a widespread change in the walls of the small arteries. *Buhl* holds that it is due to the over-nourishment of the heart. According to the investigations made up to the present time, there can be no doubt that the hypertrophy of the heart in diseases of the kidney is dependent upon an increase of the aortic pressure. This increase is best explained by an increase of the resistance in the small arteries of the entire body, due to the contraction of the small arteries. This contraction must be brought about either through the direct action of the urinary substances contained in the blood or by some reflex stimulus from the kidneys, or finally by some influence exerted upon the vasomotor centre. It is possible that the heart also may be excited to increased activity.

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## II. Local Hyperæmia and Local Anæmia.

§ 35. To the blood is assigned the function of supplying all the organs and tissues of the body with nourishment. The cells and cellular structures of which the various tissues are composed are able to maintain their existence without the advent of fresh nutritive material only for a short time; and for this reason the majority of the tissues are supplied with blood-vessels, and those not possessing vessels of their own are placed in the most intimate connection with vascular structures.

The demands of the different tissues for blood are not always the same, and there is consequently in the various tissues a corresponding increase or decrease in the afflux of blood and in the amount of blood contained within an organ or tissue at any given moment. An organ rich in blood is designated as **hyperæmic**; one poor in blood as **anæmic**.

The regulation of the amount of blood which an organ receives under physiological conditions is brought about by a change of the resistance in the afferent arteries; and this change is effected entirely through a variation in the calibre of the arteries. Since the total mass of the blood in the body is not sufficient to fill all the vessels at the same time, an extra supply of blood to one organ is possible only by supplying a less amount of blood to other parts. The change in the calibre of an artery is determined, aside from the blood-pressure, by the elasticity of the artery-wall and the degree of contraction of its smooth muscle-fibres. These fibres are the regulating element; their activity is dependent partly upon influences affecting them directly, and partly upon nervous influences from the intravascular plexuses and from the vasomotor centres in the medulla oblongata and in the spinal cord, some of these stimulating, others inhibiting the muscular action.

When the departures from the average blood-supply of any part of the body overstep the physiological limits, or if such variations arise without physiological causes, or are unduly prolonged, the condition is spoken of as **pathological hyperæmia** and **pathological anæmia**. These conditions are in part brought about by the same regulating mechanism which governs the normal blood-supply of an organ.

§ 36. **Hyperæmia** of an organ is caused under **pathological conditions** either by an increase in the arterial supply or through an obstruction and damming-back of the venous outflow; and there are distinguished, accordingly, two forms, an *active* or *congestive* (arterial) **hyperæmia** and a *passive* or *stagnation* (venous) **hyperæmia**. **Active hyperæmia** arises through an *increase of the afflux of blood (congestion)*, and may be either *idiopathic* or *collateral*. The first of these plays the more important rôle. It depends upon a relaxation of the muscular tunics of the artery, which may be brought about either by paralysis of the *vaso-constrictors* (*neuromyolytic congestion*), or through a *stimulation of the vasodilators* (*neurotic congestion*), or through direct *weakening and paralysis of the muscles* (as, for instance, by heat, bruising, action of atropine, brief interruptions of the blood-current), or, finally, through a *diminution of the external pressure exerted upon the vessels*. *Collateral hyperæmia* is merely the result of a diminished flow of blood to other parts. It oc-

curs first in the immediate neighborhood of the parts whose blood-supply is lessened; later, the blood may be driven also to such other more distant organs as may require it.

Active hyperæmia is characterized by a more or less *marked redness* and *swelling* of the part, which are very striking in tissues rich in blood-vessels. The blood flows through the widened channels with increased velocity, and lends to the tissue the color of arterial blood. Superficial tissues which are exposed to cooling become as a result of the increased blood-supply warmer than the neighboring tissues which are less richly supplied.

**Passive Hyperæmia** arises through the *retardation* or *obstruction* of the flow of blood from the veins. A *general passive congestion* of the systemic veins occurs in those cases in which, through weakness of the heart's action, valvular insufficiency or stenosis, or obstructions to the pulmonary circulation, the emptying of the large veins into the right heart is hindered. In the pulmonary circulation stagnation of the blood-stream may be brought about by any cause hindering the outflow of blood from the lungs, particularly valvular lesions of the left heart, weakness of the left side of the heart, and, more rarely, obstructions in the systemic arteries. Not infrequently such a stasis of the pulmonary circulation may reach such a degree that the blood is dammed back into the right heart, and into the veins of the systemic circulation (see §§ 33 and 34).

**Local passive congestion** may arise directly from the fact that the progress of blood through the veins is not adequately supported by the activity of the muscles and the aspiration of the blood from the veins during the inspiratory enlargement of the thorax. The absence of the first factor is most apparent in the case of the branches of the inferior vena cava; as, for example, in individuals who pass a large part of their time sitting or standing without active bodily exercise, so that the emptying of the deep-seated venous branches into the vena cava is dependent almost wholly upon the activity of the vein-walls, which by virtue of their elasticity and contractility work against the pressure of the column of blood resting upon them. The absence of the inspiratory aspiration of the venous blood may, on the other hand, make itself felt in disturbance of inspiration through inflammation or other disease-processes of the lungs or pleura.

A further cause of local passive hyperæmia consists in the narrowing or closing of individual veins, as in the case of compression, ligation, formation of thrombi (§ 38), and the invasion of the veins by new-growths. For example, the pregnant uterus or a pelvic tumor may compress the pelvic veins, a thrombus may obstruct the cerebral sinuses or the femoral or portal veins, or a sarcoma of the pelvis may grow into the large pelvic veins.

When, through the above-mentioned processes or through ligation, single veins become occluded, the effect of the occlusion is often very insignificant, inasmuch as the veins concerned may possess free communication with other veins, so that but slight obstruction is offered to the outflow of the blood. If, on the other hand, the occluded vein possesses no collateral communications, or very small ones which are inadequate for the passage of the blood—as, for instance, is the case with the main divisions of the portal vein, the sinus of the dura mater, the femoral and the renal veins—there results a more or less marked passive congestion in the area supplying the given vein.

The effect of an obstacle to the outflow of blood shows itself first in

that portion of the vein lying between the obstruction and the periphery, the blood-current becoming slowed or checked entirely, while at the same time there follows a progressive filling and dilatation of the veins through the continued afflux of blood from the capillaries. If through the counteractive effect of the increasing tension of the elastic and contractile vein-walls the obstacle is overcome, the circulation is maintained, and the blood flows toward the heart through the channels which it still finds open. Not infrequently the small veins thus called upon to perform this increased labor become gradually much dilated, and are converted into larger veins. When the obstacle cannot be overcome and communicating vessels capable of dilatation are not present, the circulation comes to a standstill, and a condition of stasis (§ 41) or thrombosis (§ 38) is produced in the obstructed vessel and its tributaries.

If the congestion within a venous area extends to the capillaries, so that they become overfilled with blood, the affected tissue becomes *blue-red* or *cyanotic*, exhibiting at the same time a certain degree of *swelling*.

Both active and passive hyperæmia, observed during life, may, after death, show a very different appearance, and not infrequently disappear entirely. This is especially the case in the active hyperæmias of the skin, in part also in those of the mucous membranes. This is dependent upon the fact that the tissues, put upon the stretch by the dilatation of the capillaries, contract upon the latter, after the stoppage of the circulation, and by their counter-pressure drive the blood from the capillaries into the veins. In this way a tissue which was red during life may become pale after death. On the other hand, tissues which during life were pale or at least showed no especial redness, may after death take on a blue-red color. This takes place particularly upon the sides and back of the trunk (in those parts not pressed upon by the body-weight), on the neck, and the posterior aspects of the extremities of cadavers lying upon their backs; and is to be explained by the fact that after death the blood sinks to the most dependent parts of the body, and fills not only the veins, but finally also the capillaries. This phenomenon is known as **post-mortem hypostasis**, and the areas of discoloration as "**death-spots**" or **livores**. They appear within about three hours after death, and are the more pronounced the greater the amount of blood contained in the skin and subcutaneous tissues at the time of death.

In the internal organs post-mortem hypostasis is particularly noticeable in the pia mater, the dependent veins being usually more markedly distended with blood than those situated higher. In the lungs the settling of the blood causes an engorgement not only of the veins, but also of the capillaries.

If the general circulation during life, as a result of cardiac insufficiency, is imperfect, and there results a general passive congestion, the blood may also collect in the dependent portions of the body, partly because it is not driven out of them, and partly because it sinks into these parts from those situated on a higher level. This phenomenon is also known as **hypostasis**, and occurs particularly in the lungs (*hypostatic congestion*).

For the observation of the circulation and its disturbances during life the tongue or the web of the curarized frog, properly spread upon a glass plate, may be used (Cohnheim, *Virch. Arch.*, Bd. 40). This may be done in a very simple manner by drawing the frog's tongue over a cork ring, which is cemented to a glass plate, and fastening it to the sides of the ring with pins. The pulsating arterial current and the continuous venous stream possess a clear zone of blood-plasma, in both the normal and



the quickened circulation. If, through the ligation of the efferent veins of the tongue, passive congestion is produced and the current slowed, the plasma-zone in the veins is lost, and both veins and capillaries become greatly distended with accumulated red cells. After a certain time the tongue swells as the result of an infiltration with transuded fluid.

According to the investigations of *von Janderer* ("Die Gewebsspannung," Leipzig, 1884), the wall of a capillary vessel embedded in tissue supports only from one-third to one-half of the blood-pressure. The remaining portion is borne by the tissues, which afford an elastic resistance, and thereby maintain the tension which is necessary to keep the blood in motion. In both active and passive hyperæmia both the tissue-pressure and the tissue-tension are increased; in anæmia they are diminished.

§ 37. **Local anæmia or ischæmia**, the lack of proper blood-supply to a tissue, is always the result of a diminution in the afflux of blood. If the total mass of the blood is normal, the cause of the anæmia is purely local; if there is a general poverty of blood, the local anæmia, in part at least, is secondary.

The **pathological diminution in the blood-supply to an organ** is at times merely the result of an *abnormal increase of the arterial resistance*, due to the contraction of the muscular coats. In other cases *pathological obstructions*—such as compression of the arteries, narrowing of the arterial lumen through pathological changes in the vessel-walls, deposits on the inner surfaces of the arteries, occlusion of the vessels by emboli (compare § 20), etc.—may act as hindrances to the blood-stream.

The immediate result of the *narrowing of an artery* is always a slowing and diminution of the blood-stream beyond the point of constriction. *Complete occlusion* of an artery brings the circulation beyond the obstruction to an immediate standstill. If back of the point of constriction or occlusion the artery is provided with large arterial communicating branches—the so-called *arterial collaterals*—the disturbance of the circulation may be compensated by an increased afflux of blood through the collateral arteries; and this compensation is the more complete the larger and the more distensible are the collaterals. If the narrowed or occluded artery possesses no collateral branches in its area of distribution—if it is a so-called *terminal artery*—the slowing or cessation of the circulation beyond the point of obstruction or occlusion cannot immediately be done away with, and the affected vascular area becomes partly or wholly emptied of blood, in that, through the contraction of the arteries and the pressure of the tissue on the capillaries and veins, the blood is almost wholly driven out of the area supplied by the obstructed artery. Frequently there occurs after a time an afflux of blood from the neighboring capillaries.

When the current and the pressure beyond a *constricted point* have sunk to a certain minimum, the driving force gradually becomes unable to propel the mass of blood. The red corpuscles, in particular, cease to move, and collect in the veins and capillaries, so that the *area supplied by the artery in question becomes again filled with blood*; only not with circulating, but with stagnant blood. *The same thing occurs when, after complete occlusion of a terminal artery*, the blood slowly and under low pressure enters the vessels of the affected area from small arteries incapable of adequate enlargement, or merely through *anastomosing capillaries*. Finally, an accumulation of blood within the anæmic area may also occur by a reflux from the veins. This takes place when the intravascular pressure within this area has sunk to nothing in the arteries and capillaries, while in the veins a positive pressure exists. A condition of passive congestion in the veins favors such a reflux.

A further cause of anæmia of one organ may be found in the abnormal congestion of other organs, as in that case the total mass of the blood is not sufficient to supply adequately the remaining organs. Such an anæmia is designated *collateral anæmia*.

All *anæmic tissues* are characterized by *paleness*. At the same time they are flabby, not turgescient, and show their individual color more distinctly.

The **significance of ischæmia** lies especially in the fact that, on account of the need of the tissues for a continuous supply of oxygen and food-material, the persistence for a certain length of time of the condition of imperfect blood-supply brings about *tissue-degenerations* (compare § 1). Total arrest of the blood-supply leads in a short time to the *death* of the tissue involved. If the blood comes to flow anew into the degenerating and dying tissues in the area of distribution of an obstructed vessel, and there stagnates, an extravasation of blood into the tissue may take place, leading to the formation of a *hæmorrhagic infarct* (compare § 45).

The rapidity and completeness of the *development of a collateral circulation* after the occlusion of an artery depends upon the size and distensibility of those vessels which are in communication with those of the anæmic area. If these are numerous and distensible, the anæmic area is soon again supplied with an approximately normal volume of blood. If this is not the case the disturbance of the circulation is more slowly compensated; and the stasis and increased pressure are found to extend farther back from the point of obstruction toward the heart, so that a collateral hyperæmia occurs in vessels situated farther back toward the heart. In the further course of the process of re-establishing the circulation the resulting increase of volume and velocity remains confined to such vessels as communicate with the area of the obstructed artery, that is, confined to the capillary and arterial anastomoses, where the increase of volume and velocity become permanent. This leads further to a lasting dilatation of the vessels concerned, and at the same time to an increase in the vessel-walls, not only in thickness, but also in length, as is evident from the increased tortuosity of the vessels. According to *Nothnagel*, the phenomenon of the increase in thickness of the walls of the anastomosing arteries may be demonstrated in the case of rabbits in about six days after the ligation of an artery; and after the ligation of large vessels in their continuity, the small arteries which carry on the collateral circulation become changed in the course of a few weeks, into quite capacious, thick-walled arteries.

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### III. Coagulation, Thrombosis, and Stasis.

§ 38. Upon the *death of the individual* the **blood** contained in the heart and great vessels sooner or later **coagulates** in part, and there arise those formations which are known as **post-mortem clots**. If the clotting occurs at a time when the red blood-cells are still evenly distributed in the blood, the whole mass of the blood becomes coagulated, forming soft, dark-red masses of coagulum which are known as **cruur**. If before the clotting there occurs, through the sinking of the red cells, a separation of the blood into two layers—a substratum rich in red blood-corpuscles, and an upper fluid layer containing none and consisting only of the plasma—then, if the latter coagulate, there will be formed soft, gelatinous, light-yellow, elastic lumps and stringy masses having a smooth surface and not adherent to the vessel-wall, which are known as *lardace*.

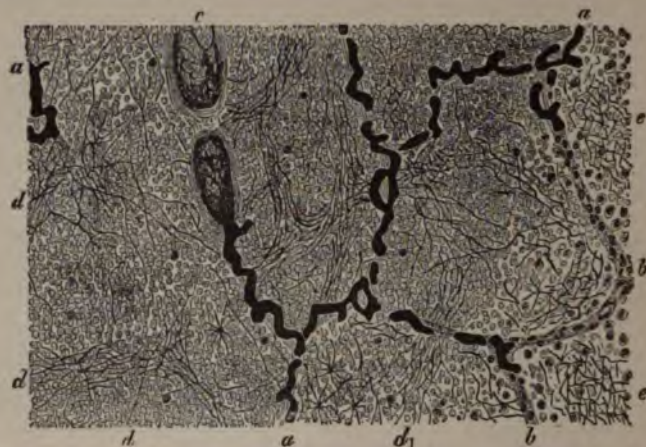


FIG. 12.—Coagulated blood in a fresh hæmorrhagic infarct of the lung. (Müller's fluid; hæmatoxylin and eosin.) *a*, Alveolar septa without nuclei, containing capillaries filled with dark bluish-violet, homogeneous thrombus-masses; *b*, septa containing nuclei; *c*, vein filled with red thrombus; *d*, *d*<sub>1</sub>, alveoli filled with firm blood-clots; *e*, alveoli filled with serous fluid, fibrin, and leucocytes.  $\times 90$ .

*ous clots* or as *fibrinous deposits*. Through the inclusion of red cells in these formations, they may present in parts a red or reddish-black color; if large numbers of leucocytes are present, they may have a whitish color.

When blood is drawn from an artery or vein and received into a vessel, coagulation will occur within a short time, as the result of the adhesion of the fluid to the sides of the receptacle. The entire blood-mass becomes changed into a soft coherent mass. When freshly drawn blood is beaten with a solid body, the surface of the latter becomes covered in a very short time with felt-like fibrin. If within the body large quantities of blood pass out into the tissues—as, for example, into the pericardium or into the lungs—coagulation may occur here likewise, and the extravasated blood may in this way acquire a firm consistency.

Under certain conditions there may be formed *within the heart or blood-vessels during life*, firm deposits, which in part are similar to cruor, and in part to the fibrin-masses formed by whipping the blood. These formations are known as **thrombi**, and the process which leads to their formation as **thrombosis**. According to their color they may be distin-

guished as *red*, *colorless* or *white* (that is, yellow or grayish-white), and *mixed thrombi*.

The **coagulation of the blood** is a peculiar process, difficult of exact interpretation. **Histologically**, it is characterized, both in extravascular clotting (Fig. 12, *d*, *d*,) and in intravascular as well (Fig. 13), by the formation of little *rods and threads* between the red cells, at one time arranged in a meshwork, at other times in stellate or fascicular groups around centres. These little rods and fibres are known as **fibrin**; and are in part smooth and shining, in part covered by little granules, or partly interrupted by granules, or are composed entirely of such collected together. Besides the threads there occur also *free granules*, *granular masses*, and *blood-plates* of varying size and form; and not infrequently such formations lie in the centre of the fibrin-stars. At times the stellate and fascicular forms of fibrin are found arranged about leucocytes or attached to endothelial cells of the intima of the vessel.

In the *red blood-cells* there occur here and there degenerative appearances, in the form of plasmolysis, plasmorrhaxis, and plasmoschisis. In *plasmolysis* or *erythrocytolysis* there occurs a passage of soluble substances from the red cells into the blood plasma, so that the red cells become smaller, and the so-called microcytes and red blood-cell "shadows" are produced. At the same time individual cells may become swollen.

In *plasmorrhaxis* or *erythrocytorrhaxis* and in *plasmoschisis* or *erythrocytoschisis*, bright, shining globules arise from the red cells, or the latter become covered with little prickly-like projections, or come to resemble mulberries, or send out protoplasmic processes. Through the snaring-off of these prominences round, disc-like, angular, or thread-like bodies are formed, which are partly homogeneous and partly finely granular, and not infrequently enclose larger shining bodies. Finally, the red cells may break up into disc-like or globular pieces, and finally into granules. The formations known as *blood-plates* are nothing more than *peculiarly formed products of plasmorrhaxis and plasmoschisis of the red cells*; and it is possible to distinguish among them those which are colorless, those containing hæmoglobin, and homogeneous and granular forms.

In fresh coagula, changes cannot usually be demonstrated in the *colorless corpuscles of the blood*; but in the later course of the process degenerative appearances are found in these also.

Between the destruction of the red blood-cells and the coagulation of the blood, both extra- and intravascular, there exist undoubtedly close relations; that is, coagulation is set into action through the occurrence of changes in the red cells as above described. According to our present knowledge, it must be assumed that many red cells, probably the oldest ones, very easily suffer such changes, so that, for example, adherence to a diseased portion of the vessel-wall, which is prevented by the normal condition of the intima, is sufficient to cause a disintegration of certain red cells, with formation of blood-plates, and later coagulation and thrombus-formation. The origin of coagulation has also been regarded as due to plasmolysis and plasmorrhaxis of the leucocytes; further, similar degenerations of the endothelium may also induce coagulation. The possibility that the endothelial cells play a certain part in the origin of coagulation cannot be excluded, but it must be emphasized that the degenerative changes ordinarily preceding coagulation cannot be demonstrated in these cells. The facts brought forth, particularly by Hauser and Zenker, that the fibrin-threads not infrequently are attached to endothelial cells, or leucocytes, or to the remains of such cells, do not prove that these are



the *exciters* of coagulation, or that they offer *material* for the formation of fibrin; inasmuch as the deposit of the fibrin upon these cells may be due to purely mechanical causes.

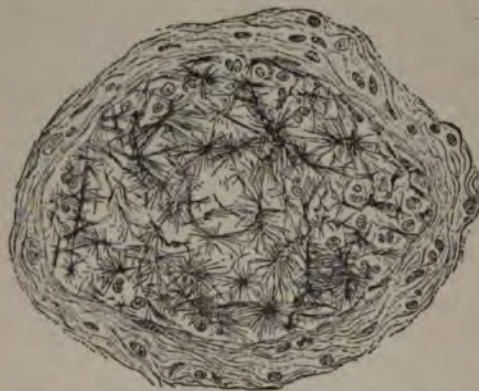


FIG. 13.—Bundles and star-shaped clusters of fibrin threads within a blood-vessel. (Fibrin stain.) Preparation taken from an inflamed tracheal mucous membrane.  $\times 500$ .

The **chemical processes** concerned in coagulation cannot at present be explained. It is assumed that for its occurrence the presence of a *fibrinogenic substance*, a *ferment* (*thrombin*), and certain *salts*, particularly *calcium salts*, is necessary; and that the fibrinogenic substance is an albuminoid body belonging to the *globulins*, which is present in the blood-plasma, while the ferment is produced by the cells. According to A. Schmidt, thrombin is derived from a parent-substance, prothrombin. By means of the

thrombin there is formed, in an as yet unknown manner, from the globulins pre-existing in the alkaline solution, a greatly swollen albuminoid body, which is precipitated by the calcium salts contained in the plasma. In the process of coagulation we must, therefore, recognize two stages, namely, the stage of the production of the fibrin-ferment, and the stage of the action of the ferment or coagulation proper.

According to Pekelharing, on the other hand, thrombin is a calcium compound of prothrombin, which arises from the cellular elements of the blood; and coagulation consists essentially in the fact that thrombin carries calcium over to the fibrinogen, whereby the insoluble calcium-compound, fibrin, is formed. Hammarsten, on the contrary, is of the opinion that calcium is carried down with the fibrinogen only as a contamination, and has no significance in the change of fibrinogen to fibrin, in the presence of thrombin. According to his theory, the calcium salts are a necessary factor only for the change of prothrombin into thrombin.

The **red thrombus** is formed under such conditions as the complete stoppage of the circulation or a marked slowing of the same, and comprises the total mass of the red cells (Fig. 14). The precipitated fibrin forms granules (Fig. 14, *b*) and threads (*a*). In fresh clots in

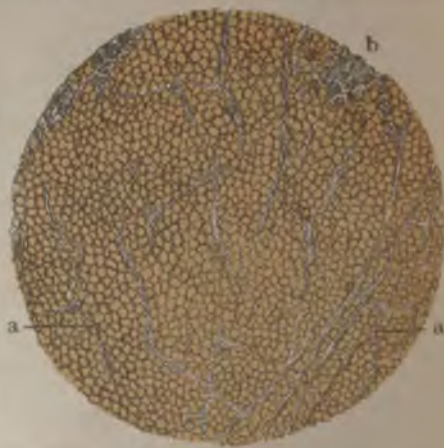


FIG. 14.—Section through a red thrombus formed in one of the veins of the thigh-muscles, after occlusion of the femoral vein. (Müller's fluid; hæmatoxylin.) *a*, Fibrin-threads; *b*, leucocytes and granular masses.  $\times 250$ .

small vessels, it is not infrequently possible to demonstrate after death, by means of special methods, the presence of bundles and star-shaped clusters of fibrin-rods (Fig. 13), which radiate from centres of coagulation. In such cases, however, it is often impossible to distinguish with certainty to what extent the coagulation is intravital or to what extent post-mortem. Such form of coagulation is most frequently observed in inflamed tissues, and the conclusion is warranted that changes in the blood occurring in such inflammatory areas are the cause of this variety of fibrin-formation.

Immediately after its formation the red thrombus is soft and rich in the fluids of the blood; later it becomes tougher, denser, and more dry, as the fibrin contracts and squeezes out a portion of the fluid. At the same time it becomes paler, brownish-red or of a rust-color, inasmuch as the blood-pigment undergoes changes similar to those occurring in extravasations.

The **cause of the ante-mortem intravascular coagulation** is to be found either in an *increase in the production of fibrin-ferment or fibrinogenic*

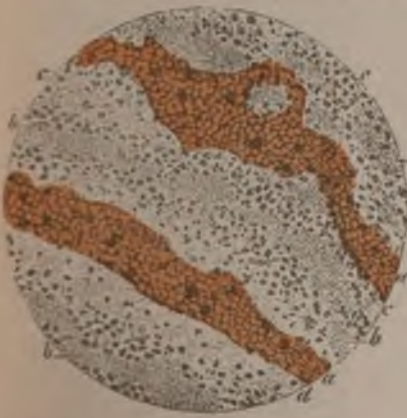


FIG. 15.—Section from a mixed thrombus rich in cells. (Müller's fluid, hæmatoxylin.) *a*, Red blood cells; *b*, granular masses; *c*, reticular fibrin containing many leucocytes; *d*, threads of fibrin in parallel arrangement.  $\times 200$ .



FIG. 16.—Section from a white thrombus containing but few cells. (Müller's fluid; hæmatoxylin.) *a*, Granular masses; *b*, fibrogranular fibrin forming a net-like reticulum; *c*, fibrin-threads in parallel arrangement.  $\times 200$ .

*substances* or in a *diminution of the power possessed by the normal vessel-wall of inhibiting coagulation*. Under certain conditions the more marked adhesion of the blood to a degenerated area in the vessel-wall may in itself be sufficient to induce coagulation. This occurs accordingly in ligated vessels, when the endothelium at the point of ligation is injured. It takes place, furthermore, when, as the result of the disintegration of great numbers of red cells, fibrin-ferment is set free in large amounts into the blood-stream—a condition which can be brought about by the injection of laked blood, in which the red cells are for the greater part destroyed.

**White, mixed, and often distinctly laminated thrombi** arise in the *flowing blood*, and consist of masses of yellowish color, or of various shades of red, or of alternating layers of red and white. The microscopical examination shows them to consist of granular and thread-like masses (Figs. 15 and 16), leucocytes, and red cells, which in varying pro-



portion and arrangement make up their structure. White thrombi may consist almost entirely of granular masses (Fig. 16, *a*) and fibro-granular fibrin, which in some cases is arranged in a meshwork (*b*), in others in fibres running nearly parallel (*c*) which enclose few leucocytes. In other cases the number of cells may be much greater. In mixed thrombi (Fig. 15), granular fibrin (*b*), more rarely hyaline masses, thready fibrin (*c*, *d*), and red blood-cells (*a*), in varying proportion and in alternating stratification, constitute the thrombus-mass, and all of these elements enclose more or less numerous, often many leucocytes.

The *fibrogranular masses* which form part of the structure of the thrombus are composed of **precipitated fibrin**. The *granular* and *hyaline*

*masses*, on the other hand, probably arise directly from the products of the **plasmoschisis and plasmorrhaxis of the red blood-cells**, in particular from the **blood-plates**. In large thrombi they often show a coral-like arrangement.

The causes of the formation of white and mixed thrombi are especially: *changes in the intima of the heart and the vessels and diseases of the vascular apparatus*, which lead to a *general or local slowing or irregularity of the blood-stream*. The formation of thrombi may be studied directly, in suitable subjects, under the microscope, both in the case of cold-blooded and warm-blooded animals; and the observations made in this line, especially by Bizzozero, Eberth, Schimmelbusch, and Löwit, have led to very important results.



FIG. 17.



FIG. 18.

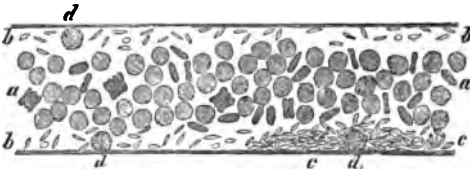


FIG. 19.

FIG. 17.—Rapidly flowing blood-stream. *a*, Axial stream; *b*, marginal zone with isolated leucocytes, *d*. (After Eberth and Schimmelbusch.)

FIG. 18.—Moderately slow blood-stream. *a*, Axial stream; *b*, peripheral zone with numerous leucocytes, *d*. (After Eberth and Schimmelbusch.)

FIG. 19.—Markedly slow current. *a*, Axial stream; *b*, peripheral stream with blood-plates; *c*, collection of blood-plates; *d*, *d'*, leucocytes. (After Eberth and Schimmelbusch.)

When the blood flows with normal velocity through a blood-vessel, there may be seen under the microscope a broad, homogeneous red stream in the axis of the blood-vessel (Fig. 17, *a*), while at the sides there lies a clear plasma-zone (*b*) free from red cells. This may be observed in the arteries, veins, and large capillaries, but is best seen in the veins, while in the small capillaries, which are just large enough to permit the passage of the red cells, this difference between the axial stream and plasma-zone is not present.

In the axial stream the different constituents of the blood-stream are not recognizable; in the plasma-zone there appear, from time to time, white blood-corpuscles (Fig. 17, *d*) which roll slowly on along the vessel-wall.

If the blood-stream becomes retarded to about the degree that the red cells of the axial stream are indistinctly recognizable (Fig. 18, *a*), the

number of white corpuscles, which roll slowly along in the plasma-zone, at times adhering to the vessel-wall, becomes constantly increased (Fig. 18, *d*), so that they finally come to lie in great numbers in this zone.

If the current is still further retarded so that the red cells become plainly recognizable (Fig. 19, *a*), there appear in the peripheral plasma-zone, in addition to the colorless blood-corpuscles (*d*), also blood-plates (*b*), which increase more and more in number with the progressive retardation of the current, while the leucocytes again become diminished in numbers. When total arrest of the blood-current finally occurs, there follows a distinct separation of the corpuscular elements in the lumen of the vessel.

If, in a vessel in which the circulation is retarded, the intima is injured at a certain point by compression or crushing, or by means of chemical agents, as corrosive sublimate, nitrate of silver, or sodium chloride, and if the lesion of the wall does not lead to a complete stoppage of the circulation, *blood-plates* may be seen *adhering to the injured portion of the wall*; and in a short time the injured spot is covered with many layers of the same (Fig. 19, *c*). Often, more or less numerous *leucocytes* (*d*.) become embedded in this mass, and their number is the greater the more numerous these are in the plasma-zone. Under certain conditions they may be very numerous and partly cover up the blood-plates. In case of great irregularity of the circulation or more severe changes in the vessel-wall, *red cells* may also drop out of the circulation and *become adherent* to the vessel-wall or the colorless deposit already formed. Not infrequently portions of the thrombus-mass are again torn loose, in which case a new deposit of blood-plates occurs. The vessel may finally be closed as the result of a long-continued deposit of the blood-elements.

When at any point blood-plates in large numbers have become adherent to the vessel-wall, they become after a time coarsely granular at their centre, and finely granular or homogeneous at their periphery, and become fused together into one compact mass. The final result of this process is the formation of a colorless *blood-plate thrombus*, within which more or less numerous *leucocytes* may be imprisoned. Eberth designates the sticking together of the blood-plates as *conglutination*, their fusion into a coherent thrombus-mass as *viscous metamorphosis*.

If we compare the observations made upon warm-blooded animals, by Bizzozero, Eberth, and Schimmelbusch, and more recently by Löwit, with the histological findings in thrombi occurring in the human subject, we are warranted in drawing the conclusion that the formation of thrombi in the circulating blood of man occurs in part in the same way as that observed in the lower animals. Thrombosis is, therefore, directly dependent upon two causes: namely, **disturbances of the circulation**, particularly *retardation of the current and the formation of eddies which drive the blood-plates against the vessel-wall*; and **local changes in the vessel-walls**. It is also probable that thrombosis is favored by **pathological changes in the blood**. From the variety of conditions under which thrombosis in man occurs, we must assume that at one time one cause, at another time another, plays the chief part in the formation of the thrombus, or that all three may take an equal part in the process.

If a blood-plate thrombus or a conglutination-thrombus has formed at any point, *coagulation* may subsequently occur, yielding fibrin-threads which enclose a greater or less number—often large numbers—of the cellular elements of the blood. *Conglutination and coagulation may occur*



in combination; and the frequency with which this comes to pass, judging from the composition of the thrombi occurring in man (Figs. 15 and 16), seems to denote the fact that fibrin-ferment is produced during the formation of the blood-plate thrombus, and that consequently, in the neighborhood of the conglutinated blood-plates, processes of coagulation occur in the adjacent plasma-zone of the blood-stream. If white corpuscles alone are circulating in this zone, the mass of coagulum is white (Fig. 16) and encloses a greater or less number of red cells; if red corpuscles also circulate in the peripheral zone, or if the coagulation extends into the red axial stream, mixed thrombi will be formed (Fig. 15).

If in marasmic individuals, as not infrequently happens, or in those who have been subjected to some traumatism, extensive thrombosis occurs, this occurrence is probably connected with a ferment-intoxication (Köhler, von Düring); and the local disturbances of circulation only decide the location of the coagulation. Vaquez is of the opinion that infections play a very prominent rôle in the origin of cachectic thrombi.

According to *Naunyn, Franken, Köhler, Ploss, Gyorggyai, Hanau*, and others, a more or less extensive thrombosis may be produced by the injection into the blood-vessels of laked blood, solutions of hæmoglobin, salts of cholic acid, ether and other substances: yet the results of this experiment are not constant (*Schiffer, Högges, Landeis, Eberth*), and coagulation may not occur. The probability of effecting coagulation is proportionate to the degree of disturbance produced in the blood by the substance injected.

According to *Arthus* and *Pagès*, the blood flowing from the veins becomes incapable of coagulating spontaneously, if sodium oxalate, sodium fluoride, or soaps are added to it in such quantities that the mixture contains 0.07–0.1 per cent of the oxalate, or about 0.2 per cent of the fluoride, or 0.5 per cent of soap. These salts all act by precipitating the calcium salts. If to blood, kept fluid by treatment with oxalic acid, one-tenth of its volume of a one-per-cent solution of calcium chloride is added, coagulation occurs in six to eight minutes, and the calcium salts pass into the combination of the fibrin-molecule. The fibrin-ferment can act upon the fibrinogen only in the presence of calcium salts. Under the influence of the fibrin-ferment, and the presence of calcium salts, the fibrinogen undergoes a chemical change which results in the formation of a calcium-compound, fibrin. *Hammursten*, who holds that the presence of calcium is not necessary for the change of fibrinogen into fibrin, attempts to explain the observation of *Arthus* and *Pagès*, through the assumption that the calcium salts are necessary factors for the conversion of prothrombin into thrombin.

If blood be allowed to flow beneath a layer of oil, into a vessel coated with a film of vaseline, it will not coagulate (*Freund*); and from this it may be assumed that the cause of the coagulation is to be found in the adhesion of the blood to a foreign body.

*Bizzozero*, in the year 1882, described as a new element of the blood, small, flat, homogeneous structures, which he designated as blood-plates, and regarded as identical with the hæmatoblasts described by *Hayem*. Supported by thorough experimental investigations, he assumed that it was these bodies, which in breaking up, induced coagulation; and, therefore, denied this to be a property of the leucocytes. *Rauschenbach, Heyl, Weigert, Löwit, Eberth, Schimmelbusch, Illara, Groth*, and others, have opposed the teaching of *Bizzozero*, in that they in part oppose the causal relation of the blood-plates to coagulation, and in part (*Weigert, Illara, Halla*, and *Löwit*) regard the blood-plates not as constant formed elements of the blood, but as degeneration-products of the colorless blood-corpuscles, or as a product of a precipitation of globulin (*Löwit*). From their contributions we may also gather that the disintegration of leucocytes in fluids containing fibrinogen may give rise to coagulation, so that the blood-plates are not the only fibrin-formers. According to *Groth*, the injection of large numbers of leucocytes into the blood-vessels leads to thrombosis. According to *Rauschenbach*, the dissolution of leucocytes is constantly occurring in the blood; but through the inhibitory powers of the organism, the fibrin-ferment is rendered inactive.

*Zahn*, in 1875, was the first to differentiate strictly between red, white, and mixed thrombi. He regarded the colorless substance of the white and mixed thrombi as formations, arising from colorless corpuscles, which become separated from the axial stream, attach themselves to rough places of the vessel-wall, and fuse together to form homogeneous or granular masses. Up to a few years ago most authors have accepted this view; but there can be no doubt, according to the investigations of *Bizzozero*,

*Lubnitzky, Eberth, Schimmelbusch, and Löwit*, that there is also a blood-plate thrombus in the production of which the leucocytes play only a subordinate rôle, and that the thready fibrin of thrombi also may often contain but very few leucocytes (Fig. 16).

According to *Löwit*, the blood-plates are not found in the normal blood, but appear only under certain conditions; and represent nothing more than globulin precipitated in the form of platelets. For their formation very slight changes in the circulation and composition of the blood are sufficient; and it is therefore difficult to make observations of the circulating blood without producing them. It is possible, however, by observing the greatest precaution, to demonstrate that the blood circulating in the mesentery of the mouse contains no formed elements except the red corpuscles and the leucocytes. Changes in the vessel-wall and slowing of the current lead to the precipitation and deposit of blood-plates upon the vessel-wall; and the blood-plates thus precipitated are quickly changed into a substance closely related to fibrin, whereby they become soluble with difficulty, swell somewhat, and in part present a granular appearance. The blood-plate fibrin is in its staining-reactions closely related to thready fibrin, so that the production of a blood-plate thrombus is, in fact, a form of coagulation. In cold-blooded animals, under the same conditions as those leading to the formation of blood-plates in warm-blooded animals, the globulin is precipitated in a granular form, but not in the shape of blood-plates. The small spindle-shaped elements found in the blood of cold-blooded animals and in birds, and which have been regarded by *Bizzozero, Eberth, and Schimmelbusch* as equivalents to the blood-plates, are nothing more than young colorless cells, which in part become transformed into ordinary leucocytes, and in part into red blood-cells. They possess nuclei, and can assume a round form, while the blood-plates are non-nucleated, and cannot actively change their form. Changes in the vessel-walls and slowing of the current lead in the case of cold-blooded animals to the formation of thrombi consisting essentially of leucocytes, which may be converted into granular masses. At the beginning of cell-deposition the spindle-shaped leucocytes are often deposited in great numbers.

The view of *Löwit* as to the genesis of the blood-plates I cannot accept; I hold rather that the **blood-plates are products of red blood-cells** which are either thrown off from degenerating red cells, or are formed by the disintegration of the same. I base my opinion upon the investigations which *Wlassow*, at my suggestion, carried out in my laboratory in 1898. *Wlassow* studied both the early stages of thrombosis, and the behavior of the blood-corpuscles when treated with different fluids. His observations would indicate that, on the one hand, in the beginning of thrombosis, in circulating blood, the red corpuscles become adherent, undergo changes and are converted into a granular mass; that on the other hand, a portion of the red cells (most probably those which are the oldest and are approaching their disintegration) are very unstable cells, from which there may be easily formed structures which correspond to the blood-plates, in so far as their properties are concerned. Whether such structures develop under normal conditions, or whether in the normal disintegration of the red cells the colorless elements of their cell-bodies pass immediately into solution, cannot be decided; this much only can be demonstrated: that the most diverse influences may cause a plasmolysis of the red cells with formation of the so-called blood-plates. *Arnold* has recently published observations upon the products of the red cells resulting from a process of constriction and setting free of portions of the cell; and these confirm and extend the observations made by *Wlassow* and myself.

*A. Schmidt*, in his work on the blood, published in 1892, in which he collects the results of many years of study on the coagulation of the blood, regards the fibrin-ferment or *thrombin* as a cell-derivative, which arises from an inactive antecedent substance, *prothrombin*, under the influence of certain *zymoplastic substances* which are also cell-derivatives. He likewise regards the *fibrinogenic substance* or *metaglobulin*, as a product of the disintegration of cellular protoplasm. Therefore, the substances causing coagulation as well as those producing thrombosis must all be regarded as cell-derivatives, and the *red blood-cells in particular are the source of the materials of coagulation*.

According to *Corin*, *coagulation occurs in the blood of the cadaver only when the ferment was present in the blood during life*; and the extent of the coagulation is dependent directly upon the amount of ferment contained in the blood during life. A further formation of ferment does not take place after death; on the other hand, it is probable that there is formed by the vessel-walls a body inhibiting coagulation. Between the blood of those dying suddenly (strangulation), and that of individuals dying slowly, there is only a relative difference, depending upon the amount of ferment present. A fluid condition of the blood of the cadaver can, therefore, be of no significance in so far as the diagnosis of the manner of death is concerned.

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See also § 39.

§ 39. **Thrombosis** occurs most frequently in cases of degeneration and inflammation of the intima of the heart and of the blood-vessels, as well

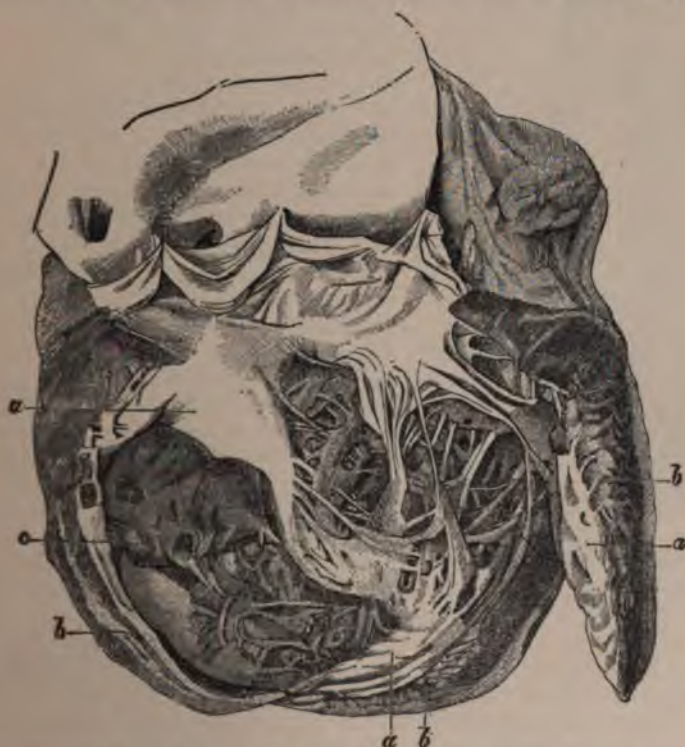


FIG. 39.—Thrombus-formation in the heart following fibroid change and aneurismal dilatation of the heart-wall. *a*, Fibroid thickening of the endocardium; *b*, fibroid areas in myocardium; *c*, thrombus. (Two-thirds natural size.)

as under certain conditions which cause a slowing or stoppage of the circulation—as, for example, compression, narrowing, or dilatation of the vessels, fatty heart, stenosis and insufficiency of the valvular orifices,

etc. Perforating wounds of the vessels, crushing of the vessel-wall, and laceration of the intima lead likewise to the formation of thrombi; and thrombotic precipitates are formed also upon foreign bodies lying in the vessels. According to the cause of the injury to the vessel-wall there may be distinguished: *traumatic*, *infectious*, and *thermic thrombi*, as well as those *produced by degenerative changes in the wall, foreign bodies, and tumor proliferation*. Thrombi occurring in enfeebled individuals with poor circulation (cardiac weakness) are usually designated as *marasmic* or *cachectic*.

Thrombi may be classed also according to their relation to the vessel-lumen. Thus thrombi attached to the wall of the heart (Fig. 20, c) or

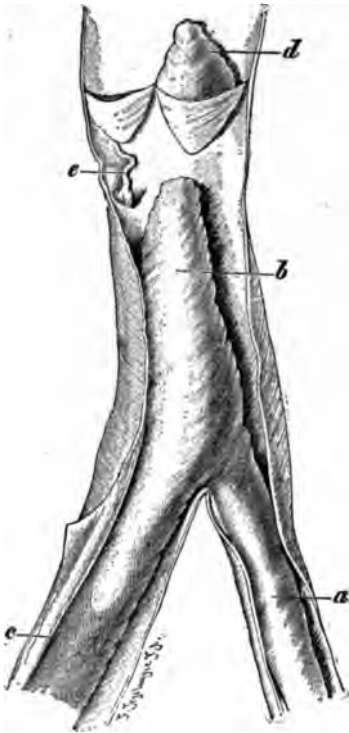


FIG. 21.—Thrombosis of femoral and saphenous veins. *a, b*, Obturating mixed and laminated thrombus; *c*, red thrombus showing peripheral attachment; *d*, thrombus protruding from a valve. (Reduced one-fourth.)

blood-vessel are known as **parietal thrombi**, those situated upon the valves of the heart or veins (Fig. 21, *d*) are termed **valvular thrombi**. In both cases the thrombi may consist only of delicate, translucent, membranous, hyaline deposits; but are often thicker and firmer and project into the lumen of the heart or blood-vessels. Their surface often shows ribbed elevations which are paler than the other portions. A thrombus completely closing the lumen of the vessel is called an **obturating thrombus** (Fig. 21, *a, b*). The coagula first formed are designated as **primary** or **autochthonous**, those subsequently deposited upon these as **induced thrombi**. Through growth by accretion a parietal thrombus may become changed to an obturating one. In this way it not infrequently happens that upon an originally white or mixed thrombus a red one (Fig. 21, *c*) is formed; the thrombosis at the beginning occurring in circulating blood, while later, after the closing off of the vessel, the blood stands still and clots *en masse*. The reverse may occur—that is, upon a thrombus originally red there may be deposited white or mixed coagula—when a red thrombus obturating a vessel becomes smaller by contraction, and thus opens up a channel for the free passage of blood.

Thrombi may occur in any part of the vascular system. In the heart they are formed chiefly in the auricular appendages and in the intertrabecular spaces, as well as upon any diseased spot (Fig. 20, *b*) in the heart-wall. They begin usually in the deep recesses between the trabeculae, but through continual accretions they form larger masses of coagula which project above the surface in the form of polypoid masses (Fig. 20), which are called **heart-polypi**. They are sometimes more or less spherical in shape, with a broad base; at other times they are more club-shaped; their surface is often ribbed. In rare cases large spherical or knobby thrombi may become loosened; and, in case they cannot pass

the ostium, lie free in the corresponding chamber of the heart. Such **free globular thrombi** are sometimes seen in the auricles in cases of stenosis and insufficiency of the auriculo-ventricular orifices, but they are of rare occurrence. After their detachment they may increase in size through the formation of new deposits of fibrin. Masses of coagula which are deposited upon inflamed valves are known as **valvular polypi**. Parietal and valvular polypi may become very large and fill up a large part of the heart-chambers.

**In the arterial trunks** thrombi may occur in a great variety of places, particularly behind constrictions and in dilatations. Occasionally in cachectic individuals with a much-degenerated arterial intima, parietal, white, or mixed thrombi, adherent to the surface, are formed in the aorta.

**In the veins** thrombi are occasionally formed in the pockets of the valves (Fig. 21, *d*), from which they may gradually protrude and develop into obturating thrombi. Often a thrombus may grow from a smaller vein (*a*), where it was primary, into the lumen of a larger vein (*b*). Thus, for example, a thrombus having its origin in a small vein of the lower extremities may finally grow into the inferior vena cava and even reach the heart. Of especial importance, because of the resulting local disturbances, are the obturating thrombi of the femoral veins, the renal veins, the sinus of the dura mater, the venæ cavæ, and the portal veins.

**Thrombosis in the smallest vessels** is most frequently the result of disease of the surrounding tissues, particularly infectious and toxic inflammations and necrotic processes. The thrombi formed are, for the greater part, hyaline; in their composition the colorless elements of the red blood-corpuscles have the chief share, fusing together into a homogeneous mass. Nevertheless, it may be demonstrated occasionally, by means of proper technique (Weigert's staining method), that they also contain thready fibrin. Thrombi of smaller vessels occur also after burns of the skin (Klebs, Welti, Silbermann) and often in cases of poisoning—for example, with corrosive sublimate (Kaufmann)—and are found especially in the smaller vessels of the lung. They frequently occur in hæmorrhagic infarcts (Fig. 12, *a*). Thrombi originating in the capillaries may develop also into the efferent veins, partly for the reason that through the obturation of numerous capillaries the blood flows more slowly into the veins, partly also for the reason that disintegrating red cells and blood-plates pass into the veins in large numbers.

The **first deposits** in the formation of a parietal thrombus consist of delicate, translucent, or whitish layers. The **fully formed thrombus** is a rather firm, dry mass, firmly adherent to the inner surface, and in color and structure varying according to the conditions mentioned above. Thrombi, originally soft and moist, undergo in time a process of **contrac-**



FIG. 22. — Remains of a thrombus of the right femoral vein occurring three years before death. *a*, Obliterated portion of the vein (the right common iliac artery was also obliterated); *b*, *c*, *d*, connective-tissue cords in the lumina of the vein and its branches; *e*, fresh thrombus. (Natural size.)



tion, and thereby become firmer and more dry. By means of such contraction vessels closed by obturating thrombi may become again opened for the passage of the blood.

In case of marked contraction, the fibrin, blood-plates, and the red blood-cells may become changed into a firm mass, which may remain in

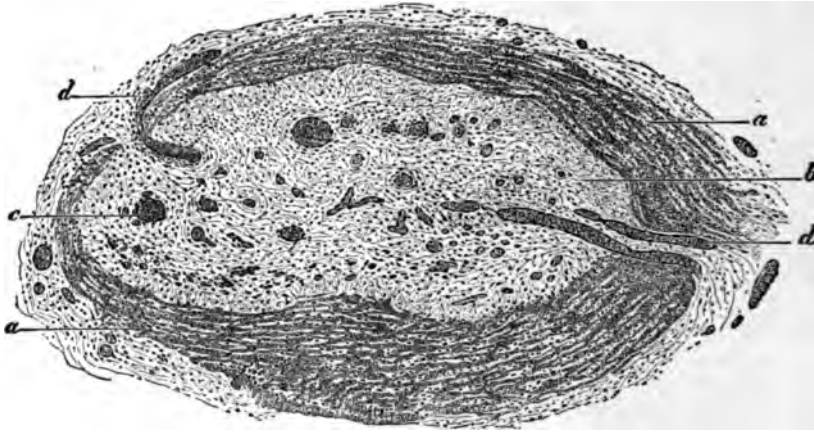


FIG. 23.—Obliteration of a pulmonary artery by connective tissue after embolic plugging of its lumen. (Müller's fluid, hæmatoxylin, and eosin.) *a*, Artery wall; *b*, connective tissue filling the vessel-lumen; *c*, *d*, newly formed blood-vessels.  $\times 45$ .

this condition for a long time, become firmly adherent to the vessel-wall, and finally undergo **calcification**. This may occur in both valvular heart-thrombi and thrombi located in the vessels. The chalky concretions formed in this manner in the veins are known as **phleboliths**; those occurring more rarely in the arteries as **arterioliths**.

Contraction and calcification are relatively favorable sequelæ of thrombosis. Much less favorable are the more frequent processes of degeneration occurring in thrombi, which are known as simple and as puriform or yellow septic softening. In **simple softening** the central portion of the thrombus becomes changed into a grayish-red, or gray, or grayish-white grumous mass, consisting of disintegrated and shrunken red corpuscles, pigment-granules, and colorless, granular débris. If the softening extends to the superficial layers, and if there is at the same time a certain strength of blood-current in the neighborhood of the thrombus, the products of disintegration may be swept along into the circulation. If thereby larger pieces become loosened and transported by the blood-stream, arterial emboli will be produced (see Fig. 2).

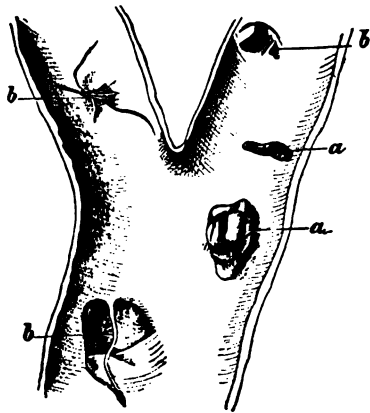


FIG. 24.—Remains of embolic plugs in a branch of the pulmonary artery. *a*, Contracted embolus traversed by connective-tissue threads; *b*, cords of connective-tissue crossing the orifices of branch vessels. (Natural size.)

In the **yellow puriform or septic softening** the thrombus breaks down into a yellow, or grayish-yellow, or

reddish-yellow, pus-like, grumous, creamy, and at times foul-smelling mass, consisting of pus-corpuscles and a large amount of finely-granular substance, composed of fatty and albuminous detritus and micrococci. This mass acts as a destructive irritant upon the surrounding tissues, giving rise to inflammation. As a result the intima becomes cloudy, and there arises a purulent inflammation in the media and adventitia, as well as in the tissues about the vessel. After a short time all the vascular coats become infiltrated and present a dirty-yellow or grayish-yellow appearance. A suppurative destruction of the tissues finally results. If puriform masses are transported by the blood-stream to other parts of the vascular system, they will give rise to metastatic foci of necrosis and septic disintegration of the tissues, and purulent inflammation, involving not only the vessel-wall but also the neighboring tissues.

The process of puriform softening of a venous or arterial thrombus, associated with a purulent infiltration of the vessel-wall, is designated **thrombophlebitis purulenta** or **thrombo-arteritis purulenta**. The inflammation of the vessel-wall may take its start either in the softening thrombus or in the tissues adjacent to the vessel. In the latter case the

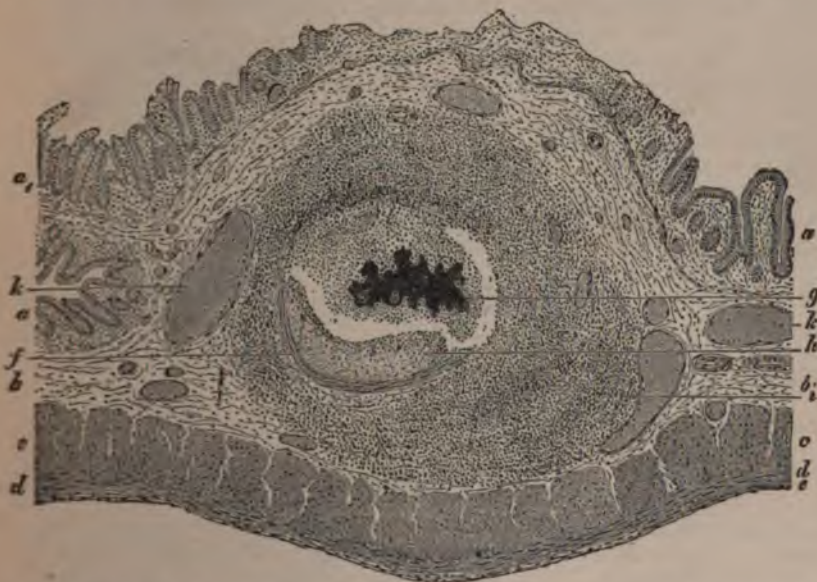


FIG. 25.—Embolism of an intestinal artery, with suppurative arteritis, embolic aneurism, and periarterial, metastatic abscess. (Alcohol, fuchsin.) *a, b, c, d, e*, Layers of the intestinal wall; *f*, artery wall; *g*, embolus, surrounded by pus-corpuscles, lying in the dilated artery which is partly destroyed by suppuration; *h*, parietal thrombus; *i*, periarterial purulent infiltration of the submucosa; *k*, veins gorged with blood.  $\times 27$ .

softening of the thrombus is coincident with the inflammation of the vessel-wall or else follows it. These processes occur most frequently in the neighborhood of purulent foci.

The most favorable sequela of thrombosis is the **organization of the thrombus**—that is, a **substitution of the thrombus by vascularized connective tissue**.

The new connective tissue develops, in the first place, from the proliferation of endothelial cells. If these have been destroyed in the for-



mation of the thrombus, the process of organization is brought about by formative cells which wander in from the outer layers of the vessel-wall. The thrombus itself takes no part in the organization; it is a dead mass which excites inflammation in the surrounding tissues. In the course of time the dead thrombus-mass is replaced by vascularized connective tissue (Fig. 23, *b, c, d*).

The cicatricial tissue formed in the place of the thrombus contracts more or less in the course of time. The cicatrices formed after ligation may thus become very small. Such a cicatrix in the continuity of a vessel may later appear simply as a thickening of the vessel-wall, or there may remain only threads and trabeculæ (Fig. 22, *b, c, d*), which cross the lumen of the thrombosed vessel, so that the blood-stream can once more pass the affected spot. Not infrequently the connective-tissue strands crossing the vessel cause a marked narrowing of the lumen; or the vessel may become completely obliterated (Fig. 22, *a*), so that the vessel for a greater or less distance becomes converted into a solid fibrous cord.

The pieces broken loose from a thrombus and carried into an artery and there lodged—that is, **emboli**—generally induce new deposits of fibrin upon their surface. Later they undergo the same changes as thrombi, and may either soften, or contract (Fig. 24, *a*), or become calcified. If the emboli are non-infective they usually become replaced by vascular connective tissue (Fig. 23, *b, c*).

In many cases the new-formation of connective tissue leads to the obliteration of the artery (Fig. 23). In other cases in the place of the embolus there is developed only a ridge of connective tissue or a nodular or flat thickening of the intima. In still other cases the lumen of the vessel is traversed by strands of connective tissue (Fig. 24, *b*), which either run separately or, interlacing, form a fine- or coarse-meshed network.

If pyogenic organisms are present in the emboli, as is very likely to be the case when the emboli arise from a thrombus lying in a suppurating focus, there is produced a purulent process (Fig. 25, *i*) at the site of the embolus (Fig. 25, *g*), and occasionally ulceration also.

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 See also § 38.

§ 40. As **stasis** or **stagnation of the blood** is designated a stoppage of the circulation without coagulation, in which condition the red blood-cells are so closely pressed together that the small vessels appear filled



FIG. 26.—Congestive stasis in the vessels of the corium and papillae of the plantar surfaces of the toes from a man dying of valvular disease, heart failure, and arteriosclerosis. (Müller's fluid, alum carmine.) Toes presented a deep violet color, and beginning gangrene.  $\times 20$ .

with a red mass of blood, in which the outlines of the individual red blood-cells cannot be distinguished (Fig. 26). The cause of this condition lies most frequently in the occurrence of a marked *passive congestion*. When the blood entering into a certain tissue-area finds no avenue of exit, the circulation in the small veins and capillaries, and even in the smallest afferent arterial branches, comes to a permanent standstill. Since from the arteries there come with every pulse-wave fresh masses of blood to the congested area, the capillaries and veins become more and

more distended and the pressure within these rises to the height of that at the point of divergence of the nearest permeable artery. In this way a large portion of the fluids of the blood are pressed out of the capillaries and veins, and as a result of this the red blood-cells become so closely packed together that their contours are no longer distinguishable, and the total contents of the vessel form a homogeneous, scarlet-red column (Fig. 26). The red blood-cells, however, are not fused together; as soon as the hindrance to the outflow is removed and the circulation restored, the individual corpuscles become once more separated from one another.

Stasis may be caused by many injurious influences which affect the vessel-wall and the blood itself. Thus, for example, *heat and cold, irritation with acids and alkalies, action of concentrated solutions of sugar and salt, action of chloroform, alcohol, etc.*, cause not only contraction or dilatation of the vessels and disturbances of circulation, but also under certain conditions produce stasis. These injurious agents act in the first place by abstracting water from the blood and vessel-walls, and further by producing essential changes in the composition of the blood-corpuscles, blood-plasma, and vessel-walls; so that the red cells become less mobile and the vessel-walls come to offer increased frictional resistance to the blood-stream, and at the same time to permit the fluid portions of the blood to pass through them the more readily. Stasis may also be produced by loss of water and drying of the tissues, an event which may occur, for example, in injuries which lay bare tissues lying within the body (intestine).

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#### IV. Œdema.

§ 41. The free fluid which permeates the tissues is essentially a transudate from the blood, though under certain conditions a portion of the tissue-fluids contained in the cells and fibres may also pass over into the free lymph. The passage of fluid from the vessels is not a simple process of filtration, but is rather to be regarded as of the nature of a secretion, accomplished by means of a specific function of the capillary walls. The fluid secreted by the capillaries mingles with the products of metabolism in the tissues, and is taken up from the tissue-spaces by means of the lymph-vessels, and through the thoracic duct is again returned to the venous blood.

Every increase in the transudation of the fluids of the blood causes first a more marked saturation of the tissues, which may be compensated for by an increased absorption through the lymph-vessels. This compensation has, however, its limits; with increased transudation from the blood-vessels there is produced a more or less permanent over-saturation of the tissues with the transuded fluids.

The condition which is produced by this collection of fluids in the tissues is known as **dropsy**, **œdema**, or **hydrops**. According to the extent of the condition there may be distinguished a *general* and a *localized hydrops*. An œdema extending over the superficial portions of the body is known as **anasarca** or **hyposarca**.

*The transudate from the blood which constitutes the œdema or the hydrops is always much poorer in albumin than the blood-plasma. The fluid collects at first in the tissue-spaces as free tissue-fluid, but may also soak into the tissue-elements themselves and cause a swelling of the cells and fibres, and, under certain conditions, the formation of vacuoles (Fig. 27), due to the collection of drops of fluid in the cells or their derivatives.*

This may be most frequently demonstrated in the epithelium of the body-surfaces and of glands, but becomes at times distinctly evident in other tissue-elements—for example, in connective-tissue cells and muscle-fibres (Fig. 27), whose fibrillæ become pushed apart by drops of fluid. Moreover, it often happens in œdematous tissues that cells become loosened from their basement-membrane, particularly in the lungs and serous membranes, where the epithelial cells in large number may be mixed with the fluid.

Tissues which are the seat of œdema appear swollen, though the degree of swelling depends essentially upon the structure of the affected tissue. The skin and the subcutaneous tissue are able to take up into their lymph-spaces large quantities of fluid, so that an extremity may become enormously swollen through œdema. In this condition it is pale, possesses a doughy consistence, and pits on pressure. On incision an abundance of clear fluid escapes, revealing the tissues thoroughly saturated with fluid.

The lung behaves in a similar way. Owing to its limited room it cannot become greatly distended, but it contains great numbers of cavities filled with air, which, in the advent of œdema, become filled with fluid, which on pressure escapes from the cut surface, generally mingled with air-bubbles.

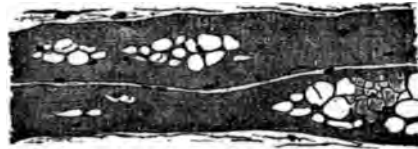


FIG. 27.—Longitudinal section of œdematous muscle-fibres from the calf muscles in a case of chronic œdema of the legs. (Flemming's solution, safranin.)  $\times 45$ .

Edematous swellings of the kidney, which may become very marked, are caused especially by the retention in the dilated urinary tubules of the water of the urine secreted by the glomeruli. In the connective tissue between the tubules large amounts of fluid collect but rarely.

The amount of blood contained in œdematous tissues is variable, and their color varies accordingly.

Body-cavities which are the seat of a dropsical effusion contain at one time a large, at another time only a small amount of a clear, usually light-yellow, rarely quite colorless, alkaline fluid, which at times contains a few fibrin flakes (see the chapter on Inflammation). Compressible organs are compressed by the effusion, the body-cavities are dilated.

A collection of fluid in the abdominal cavity is known as **ascites**.

The albumin-content of pure transudates is not the same in all the body-cavities and tissues, but differs in a pronounced degree. According to Reuss, the albumin-content of transudations of the pleura is 22.5 *pro mille*; that of the pericardium, 18.3; of the peritoneum, 11.1; of the subcutaneous connective-tissue, 5.8; of the cavities of the brain and spinal cord, 1.4. These facts may be taken as a proof of the different constitution of the vessel-walls in the various tissues of the body.

The water of the organs and tissues, according to Heidenhain (*"Versuche und Fragen zur Lehre von der Lymphbildung," Arch. f. d. ges. Phys., 49 Bd., 1891, and Verh.*

des X. internat. med. Cong., ii., Berlin, 1891) consists of three parts—the water of the blood present, the lymph of the organ under consideration, and the water contained in the cells and fibres—the tissue-water. Under certain conditions the last-mentioned may undergo considerable variation, and can increase at the expense of the free water of the blood or lymph, or diminish in their favor.

If the proportion of crystalloid substances (urea, sugar, salts) in the blood be increased, both the blood and lymph become at the same time richer in water; and this is possible only in that the substances injected into the blood pass into the lymphatics, and, by their affinity for the tissue-water, excite a passage of water from the tissue-elements. The rapid passage of the crystalloid substances from the blood into the lymph is accomplished with the aid of a force inherent in the capillary cells, and is not a simple diffusion-phenomenon. This is evident by the fact that the content of the lymph in sugar or salts is often greater than that of the blood.

§ 42. According to their etiology we may distinguish **four varieties of œdema**: *œdema from stagnation of the blood*; *œdema caused by a hindrance to the outflow of the lymph*; *œdema caused by disturbance of the capillary secretion* due to changes in the capillary walls; and *œdema ex vacuo*. The third one of these varieties is designated by the practising physician as inflammatory, hydræmic or cachectic, or neuropathic œdema, according to the clinical features of the case.

**œdema due to stagnation of the blood** arises when, as a result of the marked hindrance to the outflow of blood from the capillaries, the pressure in the capillaries rises and the fluid portion of the blood seeks a lateral outlet, so that an increased amount of fluid escapes from the vessels. The amount of the escaped fluid is the larger the greater the degree of discrepancy between inflow and outflow; it is therefore increased through a coincident increase of the blood inflow.

The escaping fluid is always poor in albumin, but with increased pressure in the veins the albumin-content is increased (Senator); the fluid may contain also a greater or smaller number of red blood-cells, the number being increased in proportion to the degree of stagnation.

The immediate result of an increased transudation from the blood-vessels is an increase in the lymph-flow, and this may be sufficient to carry off all the fluid. If it does not so suffice, the fluid collects in the tissue-spaces and there results the condition of stagnation-œdema or dropsy. According to Landerer, this occurrence is favored especially by the fact that the elasticity of the tissues becomes diminished as the result of the long-continued increase of the pressure to which they are subjected.

**Obstruction to the outflow of lymph**, as experiments in this direction have shown, is not ordinarily followed by œdema. The lymph-vessels in the different regions of the body possess such extensive anastomoses that an obstruction to the outflow of lymph does not readily occur. Even when all of the lymph-channels of an extremity are obstructed, if the amount of lymph formed is normal there results no œdema, inasmuch as the blood-vessels are able to take up the lymph again. Only the *occlusion of the thoracic duct* is likely to lead to a stagnation of the lymph and the production of œdema, particularly of ascites, but it must be observed that even in this case collateral channels may be opened up and suffice to carry off the lymph.

Although lymphatic obstruction is not ordinarily sufficient in itself to produce œdema, yet it does increase an œdema caused by an increased transudation from the blood-vessels.

**Pathological changes in the walls of the capillaries and veins of such a nature as to cause an increase in the vascular secretion**, and thereby give rise to an œdema, may occur as the result of a *long-contin-*

*ued passive congestion* and the consequent imperfect renewal of the blood. Such changes occur, however, much more frequently as the result of prolonged *ischæmia*, *lack of oxygen*, *action of high or low temperatures*, *traumatic injury*, *infection*, and *intoxication*. It is also probable that either *irritation or paralysis of the vasomotor nerves* may lead to an increase of the vascular secretion. Just what changes the vessels suffer under these conditions we are not able to state precisely, but it may be assumed that some alteration of the endothelial cells and of the cement-substance plays the chief rôle. The œdemas produced by the influences above-mentioned may be classed according to their cause as **toxic, infectious, thermal, traumatic, ischæmic, neuropathic**, etc.; and such a classification has much to commend it. Hitherto the forms of œdema here under consideration have been classed ordinarily into two groups—namely, **inflammatory and cachectic œdema**.

**Inflammatory œdema** is without doubt to be referred to an alteration of the vessel-wall, and occurs both as an independent affection, in the form of circumscribed or more diffuse swellings and hydropic effusions, and also as a coincident phenomenon in the neighborhood of severe inflammatory processes. In the latter case it is frequently designated *collateral œdema*. Inflammatory œdema is distinguished from stagnation-œdema by the fact that the transuded fluid is markedly *richer in albumin* and *in the number of white blood-corpuscles* present, and, further, in the fact that larger masses of coagula occur in it (see chapter on Inflammation). Its cause is to be sought sometimes in infectious and toxic, sometimes in thermal and traumatic influences, at other times in a temporary ischæmia.

As to **hydræmic or cachectic œdema**, it was formerly believed that *hydræmia*—that is, the diminution of the solid elements of the blood—as well as *hydræmic plethora*—that is, a retention of water in the blood—could directly cause an increased transudation from the blood-vessels. It was supposed that the vessel-walls behaved as dead animal membranes, and allowed a fluid poor in albumin to filter through more easily than one richer in albumin. The vessel-wall is not, however, a lifeless animal membrane, but must be regarded as a living organ. An *hydræmia* experimentally produced does not, according to Cohnheim, give rise to an œdema. Even when an *hydræmic plethora* is produced by the over-filling of the blood-vessels with a watered blood, and there results an increased transudation from the vessels, eventually leading to œdema, the œdema so produced occurs only when the proportion of water in the blood becomes very high, and does not develop in the same regions where the so-called *hydræmic œdema* in man appears. We must therefore assume that the œdema of cachectic individuals, as well as that occurring in individuals suffering from nephritis with impairment of renal function, depends essentially upon an *alteration of the vessel-wall*, which is caused either by the *hydræmic* character of the blood or by a poison circulating in the blood. Probably other lesions of the tissue through which the elasticity of the tissue is diminished are also concerned (Landerer). *Hydræmia* therefore *favours the occurrence of œdema*, but is not the sole cause thereof, and, in particular, does not determine its localization.

*Hydræmic œdema* is distinguished from inflammatory by the fact that the fluid is *less rich in albumin* and contains but *few corpuscular elements*.

**œdema ex vacuo** occurs chiefly in the cranial cavity and in the spinal cord, and arises in all cases in which a portion of the brain or spinal cord is lost and not replaced by some other tissue. In atrophy of the brain

and spinal cord the subarachnoidal spaces in particular become enlarged, occasionally the ventricles also. Local defects become filled either by a dilatation of the nearest subarachnoidal spaces or of the adjacent portions of the ventricles, or through a collection of fluid at the site of the defect itself.

According to *Cohnheim* and *Lichtheim*, injections of aqueous solutions of salt into the vascular system of dogs (*Vireh. Arch.*, 69 Bd.) show that hydræmia does not produce œdema. If the mass of the fluids of the blood be increased, there results an increase of almost all the secretions (saliva, intestinal juices, bile, urine, etc.), and also of the flow of the lymph; the latter, however, not universally, in particular not in the extremities. In a high degree of hydræmic plethora the abdominal organs become dropsical, but never the extremities. Control-experiments recently carried out by *Francotte* confirm the observation that hydræmic plethora artificially produced in animals causes in the first place a dropsy of the abdominal organs; but this observer was able to produce also an œdema of the skin and subcutaneous tissues.

The view that the so-called hydræmic œdema is merely the result of an increase in the absolute amount of water in the blood, is championed especially by *von Recklinghausen* and by *Pisenti*. The distribution of the dropsy is, according to *von Recklinghausen*, essentially dependent upon bodily position, external pressure, impeded circulation, difference in the innervation of different vascular areas, and the consequent difference in the fulness of their vessels.

I can subscribe to these opinions only in so far as they apply to the influence of the above-mentioned modifying factors upon the distribution of the œdema, but not as regards the main point. For the other side speak not only the experiments of *Cohnheim* and *Lichtheim* above mentioned, but also the fact that in nephritic and cachectic individuals œdema not infrequently appears at a time when no hydræmic plethora is present; and, further, in cases of hydræmic plethora no œdema may occur. I therefore look upon the increase in the amount of water as only one factor which is favorable to the occurrence of œdema.

According to the investigations of *Pickhardt*, pathological transudates constantly contain uric acid: the fluid of ascites about 0.0036 per cent; the fluid of œdema, 0.0075 per cent; and pleuritic exudates about 0.0015 per cent. Sugar is also constantly present, usually as dextrose.

*Effusions into the large serous cavities of the body* occasionally present a milky appearance, or a certain degree of opalescence. This phenomenon is most often due to the presence of chyle (*hydrops chylosus*), or of fat (*hydrops adiposus* or *chyliformis*), or of both. Moreover, the presence of different albuminoid bodies, mucoid substances (*Hammarsden*), casein-like bodies (*Lion*), lecithin (*Mitchell*, *Mattioli*, *Gross*), may produce cloudiness of the transudate. In so far as chyle is not the cause, the substances producing the cloudiness arise for the greater part from disintegrating cells.

According to *Heidenhain*, the specific function of the capillary walls plays a controlling part in the formation of the lymph. Consequently, the lymph-production can be influenced by various substances present in the blood. The crystalloid substances are quickly eliminated from the capillaries, and cause a discharge of tissue-fluid into the lymph, as has already been mentioned in § 41. *Heidenhain* has, however, found substances which, when injected, cause an increase in the transudation of water from the blood into the lymph. This may be accomplished, for example, with decoctions of the muscles of crabs and of fresh-water mussels, or of the heads and bodies of leeches, or through injections of peptone and egg-albumen. By these means the amount of lymph flowing from the thoracic duct may be increased five-, six-, and fifteenfold. At the same time the amount of organic constituents in the lymph is increased. The active substances must therefore stimulate the specific function of the cells of the vessel-walls which secrete the lymph. According to these observations, it is probable that many of the affections of the skin described as neuropathic, and which are characterized by hyperæmia associated with œdematous swelling—as, for example, urticaria, erythema nodosum, herpes zoster—are to be regarded as symptoms of intoxications coupled with nervous affections and with disturbance of the secretory activity of the capillaries. It is also possible that the secretion of the capillaries may be directly affected by nervous influences.

*Asher* and *Barbera* hold the view that the regulation of the transudation-process takes place not through the capillary walls, but through the vital activity of the tissue-cells.

*Magnus*, on the other hand, on the ground of experimental investigation (infusions of physiological salt-solutions in normal animals, irrigation of dead animals after poisoning with arsenic, chloroform, chloral hydrate, and ether, and after the removal of



the kidneys and ligation of the ureters), arrives at the following conclusions: The capillary walls during life offer a resistance to the passage of fluids; after death this resistance disappears. An injury to the capillary wall, and a diminution of its resistance, favor the occurrence of oedema. There are poisons which are able to injure the capillary-wall in such a manner that it becomes abnormally permeable.

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See also § 46.

## V. Hæmorrhage and the Formation of Infarcts.

§ 43. By **hæmorrhage** is understood the escape of all the constituents of the blood from the vessels (*extravasation*) into the tissues or upon a free surface. It may be either *arterial*, *venous*, or *capillary*, or the blood may escape from the *heart*. The blood which has escaped from the vascular system is termed an **extravasate**. For the designation of especial forms of hæmorrhage a very great variety of terms is used. If the hæmorrhagic foci are small, and form more or less sharply outlined, punctate, red or dark-red spots, they are called *petechiæ* or *ecchymoses*; if they are larger and not sharply outlined, they are known as *suggilla-*



FIG. 28.—Hæmorrhage in the skin near the knee; from a man eighty-one years of age. (Formalin, hæmatoxylin, and eosin.)  $\times 80$ .

*tions* and as *bloody suffusions*. If the affected tissue is firmly infiltrated with the escaped blood, but not torn or destroyed, the condition is spoken of as a *hæmorrhagic infarct*. If the extravasated blood forms a large mass, this is known as a *hæmatoma* or *blood-tumor*.

The blood which escapes from the vessels into the tissues collects at first in the tissue-spaces (Fig. 28). Large hæmorrhages may completely conceal the structure of the tissue. Delicate tissues, as those of the brain or spinal cord, may be destroyed by large hæmorrhages.

If the hæmorrhage occurs on the free surface of an organ, the blood either escapes externally or is poured into a neighboring cavity.

Hæmorrhage from the nose is called *epistaxis*; vomiting of blood, *hæmatemesis*; bleeding from the lungs, *hæmoptœ* or *hæmoptysis*; from the uterus, *metrorrhagia* and *menorrhagia* (during the menses); hæmorrhage from the urinary organs, *hæmaturia*; hæmorrhage from the sweat-glands, *hæmatidrosis*.

A collection of blood in the uterine cavity is designated as *hæmato-metra*, in the pleural cavity as *hæmothorax*, in the tunics of the testicle as *hæmatocele*, in the pericardium as *hæmopericardium*.

Hæmorrhages of the skin not caused by trauma are usually termed *purpura* (Fig. 28). Collections of blood and fluid beneath the epidermis in the place of the loosened deeper epithelial layers give rise to *hæmorrhagic blebs*.

Recent extravasations show the characteristic color of either arterial or venous blood. Later the extravasate shows various alterations which are characterized particularly by color-changes. Suggillations of the skin become first brown, then blue, and green, and finally yellow. In the course of time the extravasate is absorbed (see Chapter V.), and during this absorption tissue-proliferation often occurs. Large collections of blood may become partly organized into connective tissue or may become encapsulated (see Chapter VII.).

A hæmorrhage may occur, in the first place, from **rupture of the heart** or the **vessel-wall**—that is, **per rhexin** or **per diabrosin**. This is the only form of cardiac and arterial hæmorrhage. From the capillaries and veins hæmorrhage may occur also **per diapedesin**—that is, by a process in which the red cells escape through the vessel-wall without the occurrence of a tear in the same. Very often such hæmorrhages are small and of slight extent; in other cases the process continues for a longer time, and the infiltration of the tissues with red cells reaches a significant degree. Hæmorrhages by diapedesis are therefore not always small, hæmorrhages by rhexis not always large. The rupture of a capillary or small vein does not give rise to a large hæmorrhage; on the other hand, a hæmorrhage through diapedesis can reach an important size. In a given case it is not always easy, and often impossible, to decide whether the hæmorrhage has arisen through rhexis or diapedesis.

The phenomenon of diapedesis may be observed under the microscope in the frog's mesentery or in the web of its foot. If before the examination the efferent veins are ligated, the capillaries and veins are seen to be engorged with blood. After a certain time the red cells pass from the capillaries and veins (see *Cohnheim*, "Allgem. Pathol.," i., and *Virch. Arch.*, 41 Bd.). *Hering* (Sitzungber. d. Wiener Akademie, 1868, Bd. 57) regards the phenomenon as a filtration-process. As a result of the obstruction to the outflow the blood seeks to escape laterally, and is forced through the vessel-wall.

Exhaustive investigations in regard to diapedesis of the red corpuscles, as well as in regard to the escape of other elements of the body which have been introduced into the blood-vessels, we owe to *Arnold* (*Virch. Arch.*, 58, 62, 64 Bd.). *Arnold* believes that we must assume the presence of openings in the endothelial tube at the point of exit of the corpuscular elements; these openings he designated as *stigmata* and *stomata*. Later he recognized the supposed openings to be local accumulations of the cement-substance between the endothelial cells. Under pathological conditions the cement-substance becomes softened and permits the passage of the red cells.

§ 44. The **causes of interruption of continuity of the heart-wall and vessel-walls** are in part *traumatic injuries*, in part *increase of intravascular pressure*, and in part *diseased condition of the heart and vessel-wall*. Increase of the blood-pressure in the capillaries and smallest veins can lead to rupture without the aid of vascular changes, particularly in the case of marked passive congestion. The heart, normal arteries, and normal veins of large size cannot be ruptured through increase of pressure alone, but abnormally thin-walled or diseased areas in either the heart, arteries, or veins may be so ruptured. Newly formed vessels are easily torn.

**Diapedesis** may be caused by an *increase of pressure* in the capillaries

and veins, as well as by an *increased permeability of the vessel-wall*. If the outflow of the venous blood in a given vascular area be totally obstructed, diapedesis of red cells from the capillaries and veins takes place; and this is to be regarded as a result of the increased pressure in the vessels. Diapedesis as a result of changes in the vessel-wall occurs particularly after mechanical, chemical, and thermal lesions of the vessel; and it may be assumed that certain *poisons* produce especially marked changes in the vessel-walls. Further, an abnormal permeability of the vessel-walls is also observed when for a long period the vessels have not been traversed by the blood-stream, and have suffered in their nutrition in consequence.

When an individual shows a special tendency to hæmorrhage, the condition is designated as **hæmorrhagic diathesis**. Two forms may be distinguished—a congenital and an acquired.

The **congenital hæmorrhagic diathesis** or **congenital hæmophilia**, which, as already mentioned in §§ 16 and 17, belongs to the diseases which may be inherited, depends most probably upon an abnormal constitution of the vessel-walls. The composition of the blood may also be pathological, so that a hæmorrhage once started is not arrested, as usual, by the coagulation of the blood.

An **acquired hæmorrhagic diathesis** occurs, in the first place, in those diseases which are known as scurvy, morbus maculosus Werlhofii, purpura simplex, purpura (peliosis) rheumatica, purpura hæmorrhagica, hæmophilia, and melæna neonatorum, and Möller's or Barlow's disease; and, further, in many infections and intoxications—namely, septicæmia, endocarditis, anthrax, typhus fever, cholera, smallpox, plague, acute yellow atrophy of the liver, yellow fever, nephritis, phosphorus poisoning, after snake-bites, etc.; and, finally, also in pernicious anemia, leucæmia, and pseudoleucæmia. In the first group of diseases named—all of which are characterized by hæmorrhages in the skin, mucous membranes, and parenchyma of other organs and tissues (in Barlow's disease, which often occurs in children of from one and one-half to two years old in association with rickets, the hæmorrhages are subperiosteal)—the cause has been generally supposed to lie in *disturbances of nutrition and of the circulation*; but recent observations make it very probable that these affections, at least in a great part, belong to the *infectious diseases*. W. Koch is of the opinion that scurvy is an infectious disease, and that the different forms of purpura, erythema nodosum, and the hæmorrhages occurring in the new-born represent varieties of this infection. In the last few years bacteria have been repeatedly found in these conditions—namely, purpura hæmorrhagica and the hæmophilia of the new-born. In this connection should be mentioned especially the investigations of Kolb, Babes, Gärtner, Tizzoni, and Giovannini, who have found in these diseases certain bacilli which were pathogenic for animals, and which, when inoculated into the latter, produced a disease characterized by hæmorrhages. These diseases are also associated with other infections characterized by hæmorrhages, and it may be assumed that the hæmorrhages are in part caused by *local changes of the vessel-wall* which are due to *local development of bacteria*, and in part to the *injurious influence of the toxic substances produced by the bacteria themselves*.

The hæmorrhages occurring in anæmic conditions are to be regarded as the result of *anæmic degeneration of the vessel-wall*, though partly also as a result of *circulatory disturbances*.

A number of apparently spontaneous hæmorrhages are connected with

*irritation or paralysis of the vasomotor nerves*, arising either from the central nervous system or by reflex action, or through lesions of the conducting nerve-fibres. In this category belong the hæmorrhage of menstruation, many forms of hæmorrhage from the nose, intestine, and urinary bladder, also hæmorrhages from the conjunctiva, skin (stigmatization), from the normal kidney, mammary glands, from hæmorrhoids, wounds, etc. Further, certain hæmorrhages from the lungs following severe cerebral lesions are also to be considered in this connection, though in a given case it is not always possible to judge with certainty, since disturbances of respiration, as well as the aspiration of irritating substances into the lungs, may likewise lead to hyperæmia and to hæmorrhages in the lung. Finally, in cerebral disease, particularly in disease of the crura cerebri, there occur hæmorrhages from the stomach and intestines, which are dependent upon the cerebral lesion. According to von Preuschen, the condition known as *melæna neonatorum*, which is characterized by the occurrence of gastric and intestinal hæmorrhages during the first days of extra-uterine life, belongs also in this category, inasmuch as during labor hæmorrhages and effusions into the brain and its membranes not infrequently occur, as a result of which the intestinal hæmorrhages follow. By others (Gärtner) *melæna neonatorum* is regarded as an infectious disease.

*Hæmorrhages per rhexin cease* when the extravascular pressure comes to equal the pressure within the bleeding vessel, or when the narrowing of the vessel and the processes of coagulation and thrombosis close the rent. *Hæmorrhage by diapedesis ceases* through a cessation of blood-supply to the bleeding vessel, or when the abnormal intravascular pressure is lowered and the vessel-wall is restored to its normal state.

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§ 45. The **sudden closure of an artery** by thrombosis, or embolism, or by ligation, or by any other means, leads, as has already been stated (§ 37), to a stoppage of the circulation beyond the point of obstruction, after the vessel has more or less completely emptied itself by the contraction of its walls. At the same time there is an increase of pressure in the vessel from the point of obstruction back to the point of divergence of the nearest arterial branch. If the branches of the artery beyond the point of obstruction have free arterial communication with some other unobstructed artery, the latter by becoming dilated may be able to supply a sufficient amount of blood to the affected area and the circulation is thus restored.

If the area of the obstructed artery has no collateral connections through which it may draw its blood-supply, the portion of tissue deprived of blood remains anæmic and dies, thus giving rise to an **anæmic infarct**. Parenchymatous organs—as, for example, the spleen and the kidneys—present in such infarcted areas a cloudy, opaque, yellowish-white, often clay-colored appearance. The microscopical examination shows that the *tissues are dead*, the nuclei no longer staining (Fig. 29, *c, d, e, f, g*).

When the area of distribution of the obstructed vessel possesses no collateral anastomoses, as in the case of a **terminal artery**, but if, on the other hand, there is a scanty influx of blood from neighboring capillaries



or from the veins, a **hæmorrhagic infarct** may be formed. The capillaries of the area rendered anæmic by the obstruction become gradually filled once more with blood, which in part comes from the capillaries of the adjacent vascular area, and in part from the veins, from which the blood flows in a retrograde direction. The blood flowing in from the adjacent capillaries is under very low pressure, which is not sufficient to drive the blood quickly through the obstructed area into the veins. When the conditions of pressure become such that a retrograde current sets in from the veins into the capillaries, the restoration of the normal circulation becomes wholly impossible.

The imperfect circulation in the obstructed area, which through processes of coagulation in the veins (Fig. 30, *c*) and capillaries (*a*) is finally brought to a complete standstill, leads, in case there is not a restoration

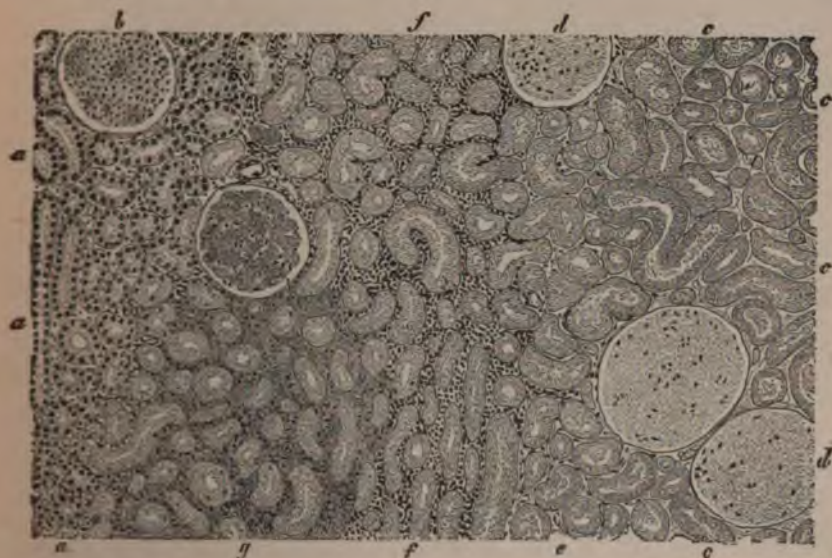


FIG. 29.—From the edge of an anæmic infarct of the kidney. (Müller's fluid, hæmatoxylin, and eosin.) *a*, Normal kidney tissue; *a*<sub>1</sub>, normal kidney-tubules with stroma infiltrated with leucocytes; *b*, normal glomerulus; *c*, necrotic tissue without nuclei, showing granular coagula in the tubules; *d*, necrotic swollen glomerulus with few nuclei; *e*, tubules without nuclei in a stroma still containing nuclei; *f*, necrotic tissue with cellular; *g*, with hæmorrhagic infiltration.  $\times 50$ .

of the normal flow of blood in the vascular system through a speedy adjustment of pressure, sooner or later to a degeneration and necrosis of the vessel-wall, and thereby to an increased permeability of the same. As a result, if the afflux of blood be continued, there occurs in the stagnated area a *diapedesis of red cells* and an infiltration of the tissue with extravasated blood corpuscles, through which the obstructed area acquires a dark-red color and a firmer consistency; a **hæmorrhagic infarct** is thus formed.

*Embolic hæmorrhagic infarcts* occur in the lungs (Fig. 30), but are formed after the embolic obstruction of an artery *only when there exists a passive congestion of the lungs*; while in the case of a normal pulmonary circulation the disturbances of circulation produced by the embolism are quickly compensated. In the systemic circulation extensive embolic hæmorrhages are confined almost entirely to the region of distribution

of the superior mesenteric artery, whose branches, though not terminal arteries, possess but few anastomoses. *Anæmic infarcts* occur especially in the *spleen, heart, kidneys, and retina*. Around the periphery of the anæmic area there is always more or less hæmorrhage, so that the pale area of the infarct is surrounded by a *hæmorrhagic border* or at least by *hæmorrhagic spots* (Fig. 29, *g*). The necrotic tissue, furthermore, becomes infiltrated with fluid, and may therefore swell (Fig. 29, *d*) and show granular or thready coagula in its spaces (Fig. 29, *c*). In the case of obstruction of the cerebral arteries or those of the extremities, or the central artery of the retina punctate hæmorrhages may also occur. Within the infarcted area the tissues are wholly or for the greater part dead, and the specific elements of the organ in particular (Fig. 29, *c, d*), die quickly. After a time an exudative inflammation arises in the neighborhood of anæmic and hæmorrhagic infarcts, with the formation

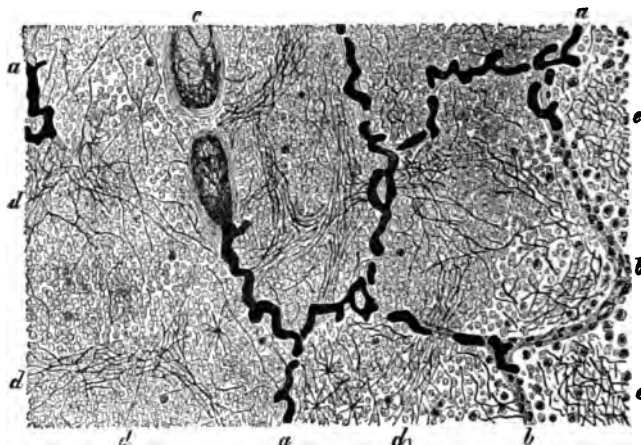


FIG. 30.—Edge of a fresh hæmorrhagic infarct of the lung. (Müller's fluid, hæmatoxylin, and eosin.) *a*, Alveolar septa without nuclei, with capillaries filled with homogeneous, dark bluish-violet thrombus masses; *b*, septa containing nuclei; *c*, vein with red thrombus; *d*, alveoli distended with firm blood-clots; *e*, alveoli filled with serous fluid, fibrin, and leucocytes.  $\times 90$ .

of a cellular (Fig. 29, *f*) or a cellular and fibrinous exudate (Fig. 30, *e*); and this is followed by tissue-proliferation through which the dead, hæmorrhagic area is gradually absorbed and replaced by connective tissue (see Part II. of Chapter VII.).

*Virchow*, who was the first to carry out extensive experimental investigations with reference to thrombosis and embolism, leaves in his published works the question of the origin of embolic hæmorrhagic infarcts still open; but expresses the opinion that most probably the vessel-walls in the obstructed area suffer changes by which they become more permeable and fragile. If a collateral circulation be afterward established, secondary hæmorrhage, exudation, and extravasation take place as the result of the changes in the vessel-wall. *Cohnheim*, who studied the results of embolism in the frog's tongue directly under the microscope, demonstrated the retrograde flow of blood in the veins, the refilling of the capillaries, and the escape of blood by diapedesis. The cause of the diapedesis he believed to be essentially the disorganization of the vessel-wall caused by the anæmia. *Litten* regarded the retrograde flow of blood from the veins as unessential, and referred the refilling of the anæmic area to an influx of blood from the capillaries of the neighboring vascular areas. He also regarded the disorganization of the vessel-walls as unnecessary for the production of infarction, inasmuch as the stagnation is sufficient in itself, as in the case of venous obstruction, to explain the diapedesis. The diapedesis is therefore increased whenever in such foci the blood coagulates in the efferent veins.

*Von Recklinghausen* considers the principal factor in the formation of a hæmorrhagic infarct to be a hyaline thrombosis of the capillaries of the obstructed area. If blood subsequently enters from neighboring vessels into the still pervious vessels of the area, it encounters resistance, becomes stagnant, and then escapes from the vessels. According to *Krebs* (*Schweizer Arch. f. Thierheilk.*, 28 Bd., 1886), emboli introduced into the circulation of animals lead to the formation of infarcts, only when blood rich in ferment is injected after the embolus, or when substances exciting coagulation are mixed with the obstructing plug.

Embolic hæmorrhagic infarcts of the lung occur in man, especially in passive congestion of the lungs; the introduction of emboli into the pulmonary arteries of animals with normal pulmonary circulation is not followed by infarction. The essential cause of the escape of blood in the case of hæmorrhagic infarction lies in the stagnation of the blood in the affected area, and in the degeneration or death of the tissue and the blood-vessel walls. The latter change may be recognized with certainty through the disappearance of the nuclei (Fig. 30, *a*). Secondary thrombosis in the vessels of the obstructed area (Fig. 30, *c*) is of frequent occurrence, and increases the stagnation and hæmorrhage, but thrombi are not always present at the time of the hæmorrhage, and, therefore, cannot be regarded as the essential factor in the production of the latter.

According to investigations by *Orth*, hæmorrhagic infarcts may be produced in dogs through the introduction of chemically irritating emboli into the pulmonary arteries.

In the lungs, in conditions of passive congestion and inflammation, there not infrequently occur extensive hæmorrhages, which, in case they are restricted to a circumscribed area, closely resemble infarcts. They are usually less sharply outlined and less firm, so that in the majority of cases they are easily distinguished from the embolic infarcts.

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### VI. Lymphorrhagia.

§ 46. **Lymphorrhagia** occurs when the continuity of a lymph-vessel is interrupted at any point and the lymph is poured out into the neighboring tissue. Since the pressure in the lymph-vessels is very low—that is, not greater than in the surrounding tissues—an outflow of lymph



from a lymph-vessel can occur only when the injured vessel lies on the external surface, or when a natural cavity is at hand into which the lymph can flow, or when, through the same cause producing the rupture, an open space is formed at the same time in the tissues. So, for example, an escape of lymph together with the blood may take place from wounds, but the outflow is stopped by very slight counterpressure. If, after the wounding of a lymphatic, the opening persists, so that there is a permanent outflow of lymph, escaping externally (as in ulcers) or into one of the body-cavities, there is formed a **lymph-fistula**, through which considerable quantities of lymph may be lost. Most important and also most dangerous is the *rupture of the thoracic duct*, which occurs sometimes as the result of traumatism, and occasionally as a result of an obstruction to the lymph-flow at some point in the lumen of the duct (after inflammation or in the course of the growth of tumors). The lymph is poured out into the thoracic or abdominal cavity, giving rise to a *chylous hydrothorax* or a *chylous ascites*, or in very rare cases to a *chylopericardium*.

In very rare cases it happens that the urine, as it comes from the bladder, has the appearance of a milk-white, or a yellowish, or, through the admixture of blood, a reddish emulsion; and contains besides albumin a large quantity of finely-divided fat-droplets. This phenomenon is known as **chyluria**. It occurs as an endemic disease in certain tropical regions (Brazil, India, the Antilles, Zanzibar, Egypt) where it is caused by a parasite, the *Filaria Bancrofti*, which inhabits the lymph-vessels of the abdominal cavity and there produces its embryos (*Filaria sanguinis*); these, during the repose of the patient in a horizontal position, swarm in great numbers in the blood, and are also found in the chylous urine. The connection between the chyluria and the invasion of the lymph-vessels has not yet been satisfactorily demonstrated by anatomical investigations; but it is probable that the chyle-like fluid does not come from the blood and through the kidneys; but, as a result of the obstruction in the lymph-circulation, chyle escapes from ruptured lymphatics of the bladder and mingles with the urine (*Scheube, Grimm*). In corroboration of this view is the fact that, at autopsy, the abdominal lymphatics exhibit marked dilatation (*Havelburg*), while the kidneys are but little changed; and further, according to an observation made by *Havelburg*, the urine obtained from the ureter showed no admixture of chyle, though chyluria was present at the same time.

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 See also § 42.

## CHAPTER V.

### Retrograde Disturbances of Nutrition and Infiltrations of the Tissues.

#### I. General Considerations Concerning the Retrograde Disturbances of Nutrition and the Tissue-Infiltrations.

§ 47. The retrograde disturbances of nutrition are characterized in general by *degeneration* of the affected tissue, often also by *diminution in size* and *disappearance of the individual tissue-elements*, the *functional capacity* of the tissue being, at the same time, *lowered*.

The *tissue-infiltrations* are characterized essentially by the *deposit in the tissue of pathological substances* which have either been formed within the body or introduced into it from without. The *functional capacity* of the part affected is likewise usually *diminished*. The *infiltration* is often *only a result of preceding degenerative changes*, or may itself constitute the *chief feature of the degeneration*.

Retrograde disturbances of nutrition may affect the body in its fully developed state, or during its period of development and growth; and in either case may lead to an abnormal smallness of the affected organ or tissue. In the former case the diminution in size is due to a disappearance of the individual elements of the affected tissue, and is designated **atrophy**. In the latter case, on the other hand, it is due to a defective development of the affected organ, as shown by a more or less rudimentary condition of its elements. If in this way an organ or a part of an organ wholly fails of development, so that it is totally absent or at least is represented only by its rudimentary anlage, the condition is designated **agenesia** or **aplasia**. But if the development of the affected part is of a certain degree, yet not reaching the normal, the condition is known as **hypoplasia**.

The **causes of agenesia and hypoplasia** are partly intrinsic, and partly extrinsic—that is, the stunting and imperfect development of an organ may depend as well upon a pathological condition of its anlage, as upon external injurious influences which may affect the developing part. The disturbance of development may further affect either the whole body or only a part of the same. In the first case there results a *dwarf*; in the second, a *stunting of individual parts or organs*.

The **causes of the tissue-degenerations and the associated atrophy** are for the greater part to be found in extrinsic harmful influences to which the tissues are exposed during life; but they may also depend upon intrinsic conditions. This latter is particularly the case when the tissues in old age reach their physiological limit and gradually become incapable of properly nourishing and preserving themselves. In many tissues a similar retrograde change, due to intrinsic causes, occurs earlier in life, as, for example, physiologically in the ovary and thymus.

As extrinsic harmful influences which may lead to degenerations

should be considered all those agencies mentioned in Chapter I. Disturbances of circulation, lack of oxygen and food supply, and intoxications play a very important rôle. *In the majority of cases degenerations are localized*, so that we may speak of **degenerations of special tissues** or of **special organs**. Not infrequently the **disturbances of nutrition are more general**, so that the entire organism suffers. Thus the picture of a general disease may be produced by a degenerative or atrophic condition of the blood—that is, a diminution in the number of red blood-cells (oligocythæmia), at times also a deficiency of hæmoglobin (chlorosis), so that a permanent condition of **insufficient blood-supply** or a **general anæmia** is produced, the nutrition of the body being correspondingly impaired.

As the result of a diminished ingestion of food, or of disturbed metabolism, and of an increased waste of the proteids and fats of the body, there may result a condition of general emaciation and weakness, often associated with anæmia, a wasting of the entire body, which is designated **cachexia** or **marasmus**. If under such circumstances it appears likely that certain substances are formed in the body, which, when taken up into the blood and tissue juices, cause a contamination or alteration of these, the condition may be spoken of as a **dyscrasia**.

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## II. Death of the Organism.

§ 48. All life comes sooner or later to an end—to **death**. When this occurs at an advanced age, without preceding well-defined symptoms of disease, it may be regarded as a normal termination of life. This occurrence may be attributed, at least in part, to the fact that the functions of certain organs necessary to the maintenance of life, become discontinued as the result of intrinsic causes; although in most cases it is impossible to exclude the influence of extrinsic influences in helping to bring about the cessation of function of the organs in question.

When death occurs prematurely—that is, at an age earlier than the average age of death in man—and when preceded by symptoms of disease, it must be regarded as a pathological phenomenon. Its occurrence under these circumstances is for the most part referable to demonstrable extrinsic influences, but at times may be dependent also upon intrinsic inherited causes. It is obviously impossible to draw any sharp line of separation between physiological and pathological death.

The causes of premature—that is, pathological—death are to be found in those influences, which have been discussed in Chapters I. and II. as the causes of disease.

An individual is to be regarded as dead when all of his functions have forever ceased. Death is inevitable at that instant in which one or more of the functions imperatively necessary to life has ceased, though it is not necessary that at that moment all the functions should have ceased. Indeed, it often happens, that after life is irretrievably lost, many organs are still capable of performing their function, and it is only after a certain time that all the organs die. *The life of the organism passes gradually, by progressive cessation of the functions of its different organs, into the state of death.*

Cessation of the functions of the heart, lungs, and nervous system results in an immediate death of the entire organism. Cessation of the functions of the intestines, liver, or kidneys leads inevitably to death after a certain length of time, often measured by days. Destruction of the sexual glands does not endanger the life or health of the affected individual, and likewise man may also spare one or more of his organs of special sense.

The occurrence of death is usually determined by the last recognizable efforts at respiration and by the stoppage of the heart. With the cessation of respiration it is impossible for any organ to remain alive after a certain short period. The stoppage of the heart likewise makes impossible any further nourishment of the tissues, in consequence of which the central nervous system very quickly becomes unable to continue its functions.

After death the body may present a variety of appearances. The aspect of the external visible portions is largely dependent upon the distribution of the blood at the time of death. An abundant supply of blood in the skin gives it a blue-red color, anæmia gives it a pale color. Further, the preceding disease may alter the external appearance of the body in different ways.

Within a certain time after death various changes occur in the tissues of the body, which in part may be regarded as the **absolute signs of death**. In the first place the *temperature of the body falls*, sometimes rapidly, at other times slowly, until it reaches the temperature of the surrounding air. It must be borne in mind, however, that the temperature at times does not begin to sink immediately after death, but first rises somewhat. The rate of cooling of the body depends partly upon the character of the body itself, and partly upon the nature of its surroundings. The time required may vary from one to twenty-four hours.

The *coldness of the dead body* is termed *algor mortis*.

At the time of death the skin for the greater part becomes pale; but after six to twelve hours, sometimes earlier, bluish-red spots appear on the skin over the dependent parts of the body. These are known as the *death-spots* or *livores mortis* (*post-mortem hypostasis*), and are due to the local accumulation of blood in the veins and capillaries of the more dependent portions. They are not found in those parts of the body subjected to the pressure of the weight of the body. Their number and size depend upon the amount of blood in the skin at the time of death. Parts which have been cyanotic during life may retain this appearance after death, especially the head, fingers, and toes. The color of post-mortem hypostasis is usually blue-red; the intensity of the color varies; in cases of poisoning with carbon monoxide it is a bright red.

The weight of the body causes flattening of those muscular parts upon which it rests.

Sooner or later there occurs a stiffening and contraction of the mus-

cles, due to the coagulation of the contractile substance (Bruecke, Kühne). This is known as the *cadaveric stiffening* or *rigor mortis*. It usually comes on about four to twelve hours after death, but may occur almost immediately, or as late as twelve to twenty-four hours. It begins usually in the muscles of the jaw, throat, and neck, and extends from them to the trunk and extremities. After twenty-four to forty-eight hours it usually vanishes, but under certain conditions may persist for several days.

Rigor mortis affects also the smooth muscle fibres; and the contraction of these in the skin gives rise to the so-called goose flesh of the cadaver.

The *decomposition of the cadaver* begins with the disappearance of the rigor mortis. Its occurrence is shown partly by the odor of putrefaction, partly by changes of color in the skin and mucous membranes, and through changes in the consistency of the tissues. The commencement and progress of putrefaction depend partly upon the condition of the body-nutrition and the nature of the disease preceding death, partly upon the conditions of the surroundings, especially the temperature. Not infrequently putrefaction may occur in local dead areas of the body, even before death of the body as a whole. When putrefactive bacteria are present in the body, decomposition of the cadaver may begin immediately after death.

As an early sign of decomposition there is usually present a greenish discoloration of the skin, appearing first over the abdomen. With the progress of putrefaction the unpleasant odor and discoloration increase; and gases are formed in the intestine, later in the blood and in the tissues, which at the same time become soft and friable.

Shortly after death the *cornea becomes lustreless and cloudy, the eyeball loses its prominence, and dark spots appear in the sclera*, which, gradually increasing in size, become confluent. These changes are due to evaporation and decomposition. If the eyelids are not closed, the *uncovered portions of the eyeball show the results of drying*. Whenever the skin has lost its epidermis the exposed tissues undergo desiccation.

If all of the phenomena of life be reduced to a minimum, there may result a condition of **apparent death** which may be mistaken for real death. Though post-mortem hypostasis, rigor mortis, and putrefaction are unmistakable evidences of death, these changes may not take place until some time after death, so that an interval is left during which it may under certain conditions be doubtful as to whether death has actually occurred. To ascertain the true condition under such circumstances it must be determined by appropriate examination whether the heart still beats, whether respiration still takes place, whether the blood still circulates, and whether the nerves and muscles retain their irritability.

Conditions which are designated as apparent death occur under a variety of circumstances, as, for example, in individuals suffering from cholera, in cases of catalepsy, hysteria, after excessive bodily exertion, violent concussion of the central nervous system, after severe hæmorrhage, suspension of respiration through hanging, strangulation, or drowning, in certain cases of poisoning, after lightning-stroke, after prolonged exposure to cold, etc. The duration of this condition is usually only short, but may occasionally be extended over several hours or even days.

According to the investigations of Fuchs ("Ueber Todtenstarre," *Zeitschr. f. Heilkunde*, 1900), the heart is the first muscle to show rigor mortis, this organ being affected at a time (in animals, after three to five hours) in which rigor mortis cannot be demonstrated in any of the skeletal muscles.

### III. Necrosis.

§ 49. The condition of *local death*, or death of individual cells or groups of cells, is known as **necrosis**. As the result of necrosis the functions of the affected tissue are forever lost.

The necrosis of a cell-group or of an entire organ is only under certain conditions immediately associated with recognizable changes of structure. The slight histological changes which the cells undergo during their death do not always permit us to determine with certainty the exact moment of cessation of life; nor does the macroscopic appearance of the visible portions of the body always inform us when a portion thereof becomes necrotic.

Necrosis is therefore evident upon anatomical investigation only when certain changes in structure have occurred, either coincidently with the death or subsequently thereto. Necrosis is shown immediately by histological changes only in the case of the action of a limited number of injurious agencies; in all other cases the necrosis is followed by such changes after a longer or shorter interval. According to the nature of the subsequent tissue-changes it is possible to distinguish different varieties of necrosis.

Histologically the **necrosis of a cell** is shown in the first place by the *disintegration and disappearance of the nucleus*, whereby the chromatin of the cell—that part taking nuclear stains—forms small clumps and granules which at times pass out from the nucleus into the cell-protoplasm, where they become dissolved and disappear (*karyorrhexis*). At other times the nucleus before its disappearance shows *signs of shrinking*, and in this condition takes the nuclear stain more deeply than under normal conditions (*pyknosis*). In other cases the nucleus *retains its form but loses its staining power with nuclear stains*, and then dissolves and disappears (Fig. 31, c, d), so that in well-fixed and stained preparations no trace whatever of the nucleus can be found (*karyolysis*). Thus, for example, in an anæmic infarct of the spleen or kidney caused by arterial embolism the nuclei of the spleen and kidney cells are lost very soon after the death of the tissue (Fig. 29, c, d, f, g). At the same time the affected area becomes strikingly pale, cloudy, yellowish-white, or cream-colored; so that the occurrence of the necrosis may be recognized by the naked eye.

The *protoplasm* of the dying cells sooner or later also undergoes *changes*, which, according to the mode of death, may in some cases begin before the cells die, or in others may take place only after the cells are dead. The kind of change is dependent upon three factors: the nature of the cells themselves, the character of the destructive influence, and the amount and character of the fluids surrounding and infiltrating the cells. Amœboid cells usually assume a *globular form* after death. Delicate and only slightly modified cell-bodies, rich in protoplasm, often become, before or after death, markedly *granular*, less frequently *homogeneous* and *lumpy*. Through the taking-up of fluid the protoplasm or even the nucleus may become *swollen* and show *drops of fluid (vacuoles)*; and this may lead to breaks in the continuity of the protoplasm (*plasmoschisis*). Not infrequently as a result of plasmoschisis *portions of the cell may be extruded or cut off by constriction*. The ultimate end of all these changes is the *disintegration of the protoplasm and the nucleus into granular masses*, this process being often accompanied by a formation of fat.

Cells which normally undergo a marked transformation, as is the case with cells showing cornification, usually present less striking changes; yet even these may swell and finally become dissolved. The morphological changes in dead cells are the least pronounced when the dying cells become *more dense and dry (inspissation)*. In this case the cells only become smaller, yet it is often seen that after the loss of the nucleus the cells become changed into *lumpy masses*.

The injurious influences which may give rise to necrosis may be divided into five groups. The first two include those which destroy the tissue directly—**mechanical and chemical forces**. Thus, for example, a finger may be crushed by extrinsic violence, and a portion of the skin may be destroyed by sulphuric acid. A third group of **injurious influences comprises those of a thermal character**. The elevation of the temperature of a tissue to 54°–68° C. for any length of time leads to its death. Higher temperatures act more quickly. Refrigeration to low temperatures likewise can be borne but a short time. A fourth group is caused by **infection** with animal or vegetable parasites. A fifth group is caused by a **cessation of the supply of nourishment and oxygen to the tissues**, and is known as **anæmic necrosis or local asphyxia**.

By many writers there is recognized besides these groups an especial one designated as **neuropathic necrosis**—that is, a necrosis resulting from a lesion of the central or peripheral nervous system. By some this form is believed to be dependent essentially upon a lesion of the trophic nerves, while by others it is attributed to disturbances of the circulation, constant pressure, and mechanical injury of anæsthetic and paralyzed portions of the body. According to the observations thus far made upon man, and the experiments carried out upon animals, external injuries and disturbances of the circulation play an important part in the production of this form of necrosis, and can never be wholly excluded.

All those factors which *seriously affect the circulation within any part* and lead to a *stoppage of the blood-supply*—such as thrombosis, embolism, closure of a vessel as a result of continued abnormal contraction, disease of the vessel-walls, or ligation, pressure on the tissue, inflammation, hæmorrhage, etc., may lead to necrosis of tissue. Not only a permanent cessation of the circulation, but also a temporary stoppage of the same lasting beyond a certain time, leads to the death of the affected tissue. Whether or not hæmorrhage occurs in such cases is immaterial, as was stated in § 45, and influences only the appearance of the affected part. *Hæmorrhagic infarction* has, therefore, precisely the same significance as an *anæmic necrosis associated with hæmorrhage*.

When death follows quickly upon the action of an injurious agent,

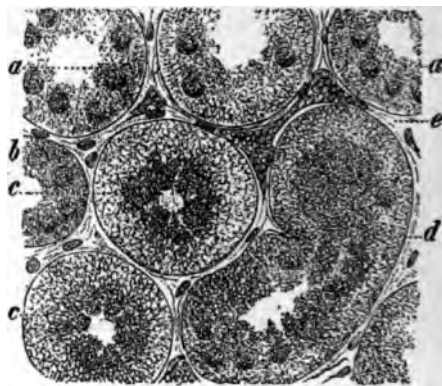


FIG. 31.—Necrosis of the epithelium of the urinary tubules in icterus gravis. (Müller's fluid, gentian violet.) a, Normal convoluted tubule; b, ascending portion of the loop; c, convoluted tubule with necrotic epithelium; d, convoluted tubule with only a part of its epithelium necrotic; e, normal stroma with blood-vessels.  $\times 300$ .

it is spoken of as **direct necrosis**. When it occurs slowly and is preceded by different tissue-degenerations it is designated **indirect necrosis** or **necrobiosis**.

Mechanical, chemical, thermal, and infectious sources of injury, as well as anæmia, may act coincidently, or separately, one after the other. When the tissue is damaged by any one of the first-named group of injurious influences, the blood itself very often suffers a change, which leads to stasis and coagulation in the capillaries, as well as in the veins and arteries, and in this way the circulation may be arrested.

Whether or not a given injury will cause necrosis of the tissue depends, not only upon its nature and severity, but also chiefly upon the condition of the tissue at the time of the injury. A tissue whose vitality has already been lowered as the result of long-continued disturbances of circulation, general marasmus, hydræmia, changes in the composition of the blood, etc., dies more easily than when in a normal condition. In severe cases of typhoid fever relatively slight pressure on the trochanters, elbows, sacrum or heels, etc., may suffice to bring about a gangrenous necrosis of the skin and subcutaneous tissues. Such forms of necrosis are known as **marasmic necrosis** or **marasmic gangrene**, and as **decubitus** or **decubital necrosis**.

The **course of necrosis**—that is, the tissue-changes resulting from the death of cells—is dependent upon the character of the affected tissue, its location, the manner of its death, and the cause of the necrosis. Further, the amount of lymph and blood in the tissue, and the opportunity afforded for the access of air and putrefactive organisms, also exert a very important influence. Tissue-changes which preceded the necrosis, such as fatty degeneration, inflammation, hæmorrhage, etc., are also of significance in determining the character of the necrosis.

As the **result of the necrosis of a certain tissue-area**, there always develops an *inflammation of greater or less intensity in the surrounding tissues* (Fig. 29, *f* and Fig. 30, *e*). This reactive inflammation is most marked when the necrotic area becomes gangrenous. Through the formation of an inflammatory zone the necrotic area becomes marked off from the surrounding tissue, and is isolated or sequestered; this process is spoken of as a *sequestering or limiting inflammation*, and the dead area thus shut off is called a *sequestrum*. A more detailed description of these inflammatory processes will be found in Chapter VII.

Excluding the more especial complications of necrosis, such as the development of specific irritating substances, five chief **sequelæ** of necrosis may be distinguished: 1. The dead tissue may be removed by *absorption*, or may be *cast off* from the surface, and *its place taken by normal tissue (regeneration)*. 2. The dead tissue is similarly removed, but instead of the normal tissue being restored, the defect is filled wholly or in part by the formation of connective tissue, the so-called cicatricial tissue. 3. The necrotic tissue is cast off or liquefied (as in the formation of a gastric ulcer through the digestion of the dead part), the defect is not filled in, and there remains an *ulcer*. 4. The necrotic tissue is partly absorbed, but a portion remains as a *sequestered necrotic mass* which not infrequently later becomes *calcified* and *surrounded by a connective-tissue capsule*. 5. The area becomes encapsulated by connective tissue, the dead tissue becomes absorbed or liquefied, and the space becomes filled with fluid, forming a *cyst*. This sequela of necrosis occurs most frequently in the brain.



The time required to kill tissue by the shutting-off of the circulation varies with the different tissues. Ganglion-cells, kidney epithelium, and liver-cells die in two hours, while skin, bone, and connective tissue may live for twelve hours or longer. Epidermis under certain conditions may remain alive for a number of days, and still retain its power of proliferation (see Transplantation).

The cause of the above-mentioned nuclear changes and of the disappearance of the nucleus is to be found in the infiltration of the necrotic tissue with lymph. These changes do not occur in those tissues to which, after necrosis, the lymph no longer obtains access. In putrefaction the nuclei disintegrate and disappear very rapidly. According to *Fr. Kraus*, tissue preserved under aseptic precautions, and protected from bacteria in moist chambers at the body-temperature, also loses its nuclei. Liver-tissue (*Goldmann*) shows this change most rapidly and completely, the tissues of the spleen and kidney more slowly and less completely, so that all nuclei may not have disappeared after eight to fourteen days. The disappearance of the nucleus occurs only in the presence of a relatively abundant supply of fluid (*Goldmann*), and may be prevented by desiccation of the tissue.

§ 50. According to the various conditions in which the tissues may be found after they have died, **four chief forms of necrosis** may be distinguished: *coagulation-necrosis*, *caseation*, *liquefaction-necrosis*, and *gangrene*.

**Coagulation-necrosis** (Weigert, Cohnheim) is characterized by the occurrence of coagulation, either *extracellular*, in the fluids about the cells; or *intracellular*, in the latter case leading to peculiar changes within the cells.

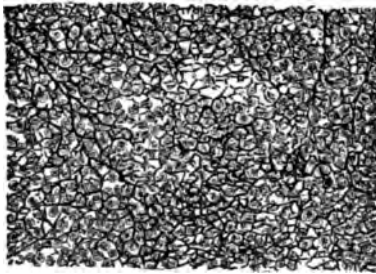


FIG. 32.—Coagulation-necrosis in the interior of a greatly swollen mesenteric lymph-gland, from a case of typhoid fever. (Alcohol, fibrin stain.) Network of fibrin between the necrotic cells.  $\times 300$ .

As *coagulation-necrosis with extracellular coagulation* may in the first place be regarded both the intravascular (Figs. 13–16) and the extravascular (Fig. 30, *d*) *coagulation of the blood*, inasmuch as this phenomenon may be regarded as the death of the blood; and in fact a destruction of cells does occur. Further, there may be considered as belonging to this class the various forms of coagulation which occur in inflammations, partly on the surface and partly in the interior of the tissues (see Chapter VII.); and which are characterized by the formation, in some cases, of stringy fibrin (Fig. 32), in other cases by the formation of granular or hyaline masses of coagula.

*Intracellular coagulation* occurs when dead cells or cell-products are infiltrated with a fibrinogen-containing lymph. The cells lose their nuclei, present either a granular (Fig. 29, *c, d, e*, and Fig. 31, *c, d*) or a hyaline lumpy appearance. They remain in this condition for a certain time and then break down into granules and become dissolved.

This phenomenon is most frequently observed in anæmic, toxic, and thermal tissue-necroses, as for example, in anæmic infarcts of the kidney (Fig. 29) and of the spleen, also in many inflammations which are associated with marked infiltration of the tissues (Fig. 32) due to exudation from the blood-vessels. In the necrosis of striped muscle, which is of very frequent occurrence in typhoid fever, the contractile substance acquires a hyaline waxy appearance and breaks up into hyaline lumps (Fig. 33, *b*).

The necrotic tissue of anæmic infarcts looks pale yellowish-white, or cream-colored. Muscles containing many dead fibres in a state of hyaline coagulation are pale red, and of a dull lustre, resembling fish-flesh.

Inflamed tissues undergoing coagulation necrosis are likewise cloudy, opaque, and grayish-white; but the color may undergo marked changes through the admixture of blood or the imbibition of bile, as in the intestine, for example.

The structure of a tissue which is the seat of a coagulation-necrosis, may still be clearly recognized if only the more delicate parts have been destroyed. When all parts have been changed, the entire tissue may be converted into a structureless, hyaline, or granular mass, containing no nuclei or but few. This change takes place very often in the necrosis of inflamed tissues which are infiltrated with exudate. Through the proper treatment of preparations there may be frequently demonstrated in these necrotic areas an intercellular stringy fibrin; this is seen occasionally in anemic infarcts, but more often in inflammatory tissue-necroses (Fig. 32).

**Caseation** is a form of necrosis closely related to coagulation-necrosis, and is characterized by either a hard or a soft cheesy appearance of the necrotic area. In the first case the dead tissue is like firm, yellowish-white, hard cheese, or similar to raw potato; in the second case it is white, soft, sometimes dry, sometimes moist, and not infrequently resembling thick cream.

Typical caseation occurs most frequently in *tubercles* and represents the characteristic end of the retrogressive changes in this condition. It also occurs in syphilitic granulomata and in very cellular tumors; inflammatory exudates may also become changed into cheesy masses.



FIG. 34.—Tissue from a partly caseated tuberculous focus, containing bacilli. (Alcohol, fuchsin, aniline blue.) *a*, Granular; *b*, lumpy masses of cheesy material; *c*, fibrocellular tissue; *d*, partly necrotic giant-cell containing tubercle bacilli; *e*, bacilli in the cellular tissue; *f*, bacilli in necrotic tissue; *g*, bacilli enclosed within cells.  $\times 250$ .

blue with Weigert's fibrin stain is often also present. It may therefore be assumed that both substances represent coagulation-products of a fluid which has escaped from the blood-vessels.

Through progressive cleavage and disintegration of the dead cells,



FIG. 33.—Hyaline necrosis or waxy degeneration of muscle, from a case of typhoid fever. *a*, Normal muscle-fibre; *b*, degenerated fibres, which have broken up into hyaline lumps; *c*, cells lying within the sarcolemma; *d*, connective tissue infiltrated with cells.  $\times 250$ .

The process of caseation of cellular tissues, which is a characteristic of tuberculous granulations, takes place gradually, and is therefore to be regarded as a form of **necrobiosis**. The cells are changed successively into non-nucleated, homogeneous, lumpy masses, which later disintegrate and break up into a granular mass (Fig. 34, *a*, *a*). At the same time with these changes there often appears between the cells a hyaline substance, sometimes forming a framework around the cells or at other times more lumpy or granular, and fibrin-like—the so-called "**fibrinoid substance**." Typical **fibrillated fibrin** (Fig. 35, *a*) staining deep



the fibrinoid substance, and the fibrin, the dead tissue is ultimately changed into a finely granular mass, in which no traces of the original structure can be perceived.

The cheesy metamorphosis of the fibrino-cellular exudate, which is found especially in the alveoli of the lungs in the neighborhood of tubercles, is brought about similarly by the disappearance of the nuclei, and the disintegration of the cells and fibrin into a non-nucleated granular mass.

The granules of the soft cheesy masses in tuberculous and non-tuberculous foci are chiefly albumin granules, more rarely fat-droplets. The ultimate fate of such masses may be partly *liquefaction* and *pultaceous softening*, partly *absorption*, and partly *desiccation* and *calcification*.

**Colliquation or liquefaction-necrosis** is characterized especially by the fact that the *necrotic parts become dissolved in the fluids present in the*

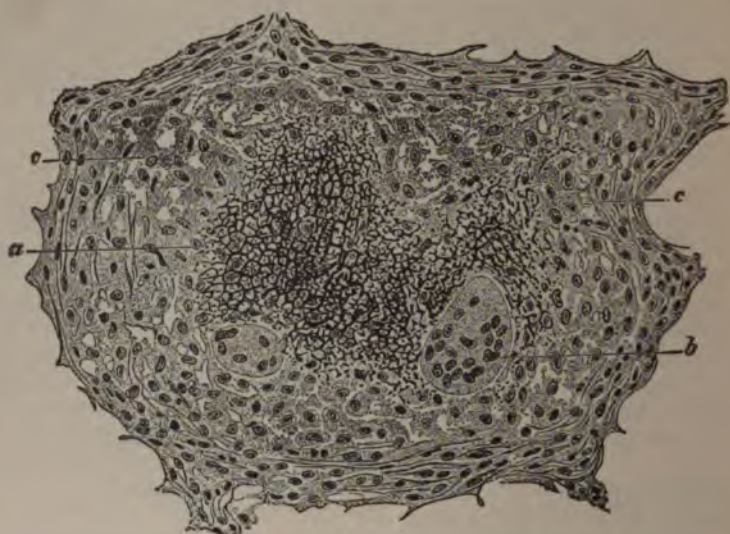


FIG. 35.—Fibrin-containing tubercle from the lung. (Alcohol, hæmatoxylin, fibrin stain.) *a*, Fibrin; *b*, giant-cell; *c*, cellular portion of the tubercle.  $\times 300$ .

*tissues*. The dissolution may be accomplished by swelling and liquefaction, as well as by a breaking up of the tissue-elements, or through a combination of these processes. Thus, for example, in burns of the second degree the cells of the epidermis, which have been killed by the heat, with the exception of the horny layer, become dissolved in the fluid exuding from the papillæ (Fig. 36, *d, f*). In the case of anæmic infarcts of the brain the *necrotic* brain-substance undergoes softening with the formation of drops and granules, and becomes converted into a milky, pultaceous mass in which the products of the destruction of the brain-tissue disintegrate into smaller and smaller particles, which, either free or enclosed within cells, become absorbed or completely dissolved. In suppurative processes of the tissues, which occur very frequently in purulent inflammations, the so-called pus-corpuscles become swollen, or disintegrate, and finally are destroyed; while the ground-substance—as, for example, the connective-tissue fibres—gradually becomes dissolved.

Necrosed areas in the mucosa of the stomach become dissolved through the digestive action of the gastric juices.

*Coagulation and liquefaction* may not infrequently follow or precede each another. For example, the products of coagulation in an inflamed area may again become dissolved. In gangrenous blebs produced by the dissolution of epithelial cells, there may occur a coagulation, the products of which are later again dissolved. Necrotic foci arising in the course of inflammations or in granulomata very often at a later stage become liquefied.

The changes described above as occurring in dead or dying tissues are not the only ones which take place during tissue-destruction. They are only the chief types which occur in the course of a relatively rapid necrosis. Many of the tissue-degenerations described in the following paragraphs also lead, not infrequently, to ultimate death of the tissue, and consequently they must be regarded as belonging to the processes classed as *tissue-necrobiosis*. Granular degeneration, fatty degeneration, mucous degen-

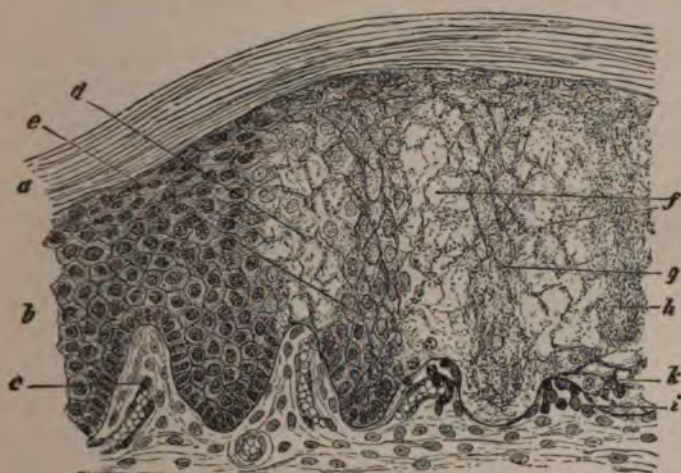


FIG. 35.—Blister of cat's paw, caused by hot sealing-wax. (Alcohol, carmine.) *a*, Horny layer of the epidermis; *b*, rete Malpighii; *c*, normal papilla; *d*, swollen epithelial cells whose nuclei are in part visible, and in part have disappeared; *e*, epithelial cells lying between the papillae, the upper ones swollen and elongated, the lower ones preserved; *f*, total liquefaction of the epithelium; *g*, swollen cells of the interpapillary cell-masses, which have lost their nuclei; *h*, a similar cell-mass which has been completely destroyed, and raised from the basement-membrane, by the coagulated subepithelial exudate *k*; *i*, flattened papillary body infiltrated with cells.  $\times 150$ .

eration, and hydropic degeneration often end in the destruction of cells; and the same result may be reached in the case of hyaline and amyloid degeneration of the connective-tissue, in that not only the ground-substance of the tissue is permanently altered, but the cells of the affected tissue also die.

According to the investigations of *Schmava*s and *Albrecht*, kidney epithelium soon becomes invisible in water, salt solutions, and diluted alkalies, in that the cells become swollen or dissolve. Epithelial cells which have become granular through anæmic necrosis retain their granular structure in the solutions named. This may be taken as a proof that coagulation has occurred with the formation of firm bodies, not soluble in dilute acids, alkalies, and neutral salts, out of elements occurring originally in the cells in a fluid state.

§ 51. Under the name of **gangrene** may be classed those forms of necrosis in which the tissue, partly through exposure to the air, partly through the agency of bacteria, suffers changes which are similar in appearance to those occurring in burned tissues. If necrotic tissue through exposure to the air loses its water by evaporation and becomes dry, the



condition is designated **dry gangrene** (*gangræna sicca*) or **mummification**. When the dead part remains moist, the terms **moist gangrene** (*gangræna humida*) or **sphacelus** may be applied. If through the agency of bacteria there occurs a *foul-smelling putrefaction*, the condition is known as a **putrid gangrene** (*gangræna fœtida*). Development of gas-bubbles as a result of the putrefactive changes leads to **emphysematous gangrene** (*gangræna emphysematosa*).

Moist gangrene and putrid gangrene are in general identical, since bacteria can develop only in moist tissues. Nevertheless a dry gangrene is not infrequently a putrid gangrene, since bacteria may develop in the tissue before drying takes place. Dry gangrene may also develop from a moist gangrene, or through the absorption of water become changed into the latter.

When the dead tissue, in either mummification or moist gangrene, contains a large amount of blood, it appears black, dark brown, or greenish-black in color, and is then called **black gangrene**. If, on the other hand, the dead tissues are anæmic, the condition is sometimes spoken of as **white gangrene**, although there is more or less discoloration of the dead part, so that the expression is often inappropriate.

In the case of gangrene of superficial parts of the body, there may be distinguished, according to the temperature of the dead part, a *cold* and

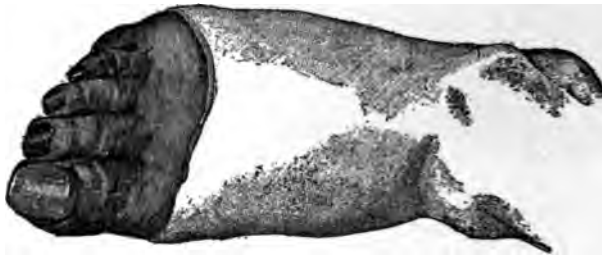


FIG. 37.—Dry gangrene of the toes, due to narrowing and closure of the arteries through arteriosclerosis.

a *warm* or *hot gangrene*, the latter designation being used when the gangrenous area is kept warm by the blood flowing through the neighboring tissues.

Gangrene may be caused by external injuries, heat, cold, corrosives, crushing, pressure, infection, etc., as well as by disturbances of the circulation.

**Gangrene due to disturbance or arrest of the circulation** occurs not infrequently in old people (*senile gangrene*), involving the extremities, particularly the toes, feet, and legs. It is usually of the dry variety, and is dependent upon general disturbances of the circulation and narrowing of the arteries of the extremities through thickening of the arterial wall (Fig. 37). The dying parts appear bluish-black from the damming-back of the blood. General disturbances of the circulation, as in heart-disease and embolism of the arteries may cause similar changes.

**Gangrene from cold** affects chiefly the tips of the extremities, nose, and ears, and is characterized by changes similar to those described above.

**Gangrene from heat** is confined to the area directly affected by the heat.

**Pressure-gangrene** or **decubitus** (*bedsore*) occurs in marasmic individuals, most frequently upon the sacrum and the heels, both of which regions are exposed to pressure when the individual lies upon his back. The bedsore begins with the formation of bluish-red spots, within whose area the tissue dies, and through the agency of bacteria undergoes decomposition and finally disintegrates. The gangrenous area may be of large extent, especially when over the sacrum; the bone may be laid bare over a large area through the destruction of the overlying soft parts.

**Toxic gangrene** occurs chiefly in ergot poisoning as a result of the contraction of the small vessels and formation of thrombi. The tips of the extremities are usually affected.

**Infectious gangrene** occurs particularly in different infections of the skin and subcutaneous tissue, and may be associated with gas-formation. In the form known as *foudroyant gangrene* different varieties of bacteria have been found; the bacillus of malignant œdema, an anaërobic bacillus (Welch, E. Fränkel, Hirschmann and Lindenthal), proteus (Hauser), and bacterium coli. Infections associated with putrid gangrene may occur in the internal organs, but affect chiefly the lungs and intestines.

A so-called **neuropathic gangrene** occurs when a tissue affected with either sensory or motor paralysis is wounded or subjected to continued pressure. It is dependent partly upon circulatory disturbances and partly upon infection. Gangrene resulting from the withdrawal of the influence of trophic nerves has not yet been demonstrated. **Symmetrical gangrene**, which affects corresponding parts of the extremities and has been regarded by many as a neuropathic disease, is dependent upon changes in the blood-vessels; likewise, the perforating ulcer of the foot (*mal perforant du pied*), which begins as a callosity following mechanical influences, and is characterized by an accompanying gangrene which rapidly penetrates into the deeper tissues, is dependent upon the closure of an artery of the foot.

In moist gangrene the tissues break down with a varying degree of rapidity, the fasciæ resisting for the longest time. As crystalline products of the chemical changes there may be found needles of fat and tyrosin, spherules of leucin, coffin-lid crystals of triple phosphate, and crystals of hæmatoidin. If the gangrene comes to a standstill, the gangrenous tissue becomes sequestered through the formation of a zone of demarcation—that is, becomes separated from the living tissue, and under favorable conditions may be thrown off from the body. In the case of necrotic portions of bone a very long time is required for sequestration. Extension of gangrene (through infection or continued circulatory disturbance) leads sooner or later to death, especially if toxic substances or bacteria are taken up into the blood or lymph.

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#### IV. Hypoplasia, Agenesis, and Atrophy.

§ 52. **Hypoplasia**, or the defective development of anlage, may affect either the body as a whole, or only single organs or parts of organs, and may occur either during the period of intra-uterine development or later during the period of post-embryonal development.

When either the entire skeleton or at least the greater part of it is under-developed, and especially if the bones do not attain their normal length, the affected individual is abnormally low in stature, and is called a *dwarf* (Figs. 38 and 39). The individual parts may be fairly well proportioned (Fig. 38), or they may be unsymmetrically developed (Fig.



FIG. 38.



FIG. 39.

FIG. 38.—Skeleton of a female cretin, thirty-one years of age, 118 cm. in height, with klinecephalic skull. The cartilage sutures of the diaphyses of the long bones and pelvic bones still show; as does also the frontal suture. The individual parts of the skeleton are, on the whole, in the proper proportion, the upper extremities alone being relatively short.

FIG. 39.—Skeleton of a female dwarf of fifty-eight years of age, 117 cm. in height, with very short extremities, and long trunk. The cartilage sutures are still present; the articular ends of the bones are thick.

39). For example, the trunk may be of normal size, while the extremities are abnormally short (Fig. 39); or both the trunk and the extremities may be abnormally small, while the head is of normal size, and consequently appears relatively too large for the small body. When the lack of development affects individual parts of the skeleton exclusively, or if it is more marked in certain parts than elsewhere, there results a stunting of individual portions of the body.

For example, defective development of the cranium gives rise to



*microcephalus* (Fig. 40) and *microencephalus* (Fig. 41); through defective development of the humerus or of the bones of the hand there results a shortening of the upper arm or of the hand; and through hypoplasia of the lateral masses of the sacrum the transverse diameter of the pelvis becomes diminished.

Of the individual organs the central nervous system (Figs. 41



FIG. 40.—Head of Helene Becker (*microcephalic*), at age of five years. (From a photograph taken by A. Ecker, in 1868.)



FIG. 41.—Brain of Helene Becker (*microcephalic*) who died at the age of eight years. (After von Bischoff.) This brain weighed 219 gm. (instead of 1,377 gm., according to Vierordt).

and 42), and the genito-urinary tract in particular suffer very frequently a stunting of development, although the intestines, heart, lungs, liver,



FIG. 42.—Hypoplasia and microgyria of the left cerebral hemisphere, from a deaf-mute. *a*, Right hemisphere; *b*, left hemisphere; *c*, occipital lobe presenting a condition of microgyria; *d*, membranous cyst in the region of the parietal lobe. (Seen from above, after removal of the cerebellum. Two-thirds natural size.)

etc., do not escape similar disturbances of growth. For example, the entire brain (Fig. 41), or only one of the hemispheres, or a part of the latter (Fig. 42, *c*, *d*) may fail of complete development. The intestine

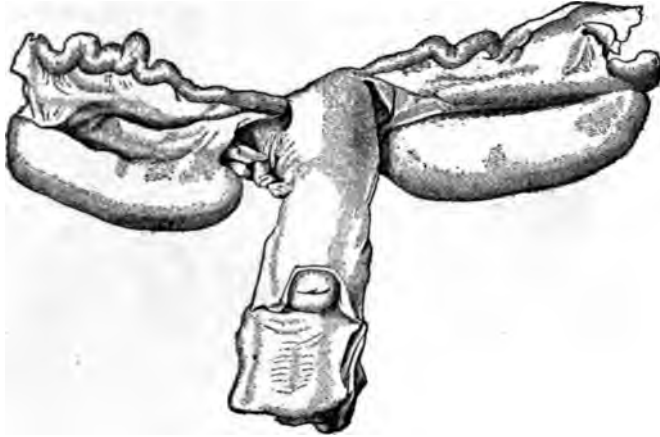


FIG. 43.—Hypoplasia of the uterus with well-developed ovaries, but without ripe follicles. From a cretin, twenty-eight years of age.

may in part be represented by a thin canal incapable of functioning (Fig. 44, *d*), or even by a solid cord (Fig. 44, *e*). The uterus not infrequently remains in an undeveloped state (infantile) (Fig. 43), and occasionally at the time of puberty the ovary (Fig. 45, *e*), or the entire internal generative apparatus, and at times also the external organs of the female may remain in the undeveloped state of the young child. A more or less marked hypoplasia of the kidney is not rare. In the development of the respiratory tract the alveoli of a portion of the lung may wholly fail to develop, so that a part of a lobe or even an entire lobe may consist only of connective tissue and dilated bronchi.

The above-mentioned examples of hypoplasia, to which many others might be added, arise partly through intrinsic causes inherent in the germ, and are therefore inheritable; and partly through the action of extrinsic injurious influences upon normal anlage during the course of development. For example, the growth of the bones may be influenced and retarded by disease of the thyroid gland or through insufficient nutrition (rachitis), disuse, and inflammation. Total failure of portions of the body or of single organs to develop is known as **agenesia**. This condition is dependent either upon the non-formation of the anlage, or upon the destruction of the latter after they have begun to develop. (See Chapter on Malformations.)



FIG. 44.—Hypoplasia of the small intestine of the new-born child. *a*, Greatly dilated portion; *b*, *c*, *d*, *e*, portion showing great narrowing and stunting; *f*, normally developed portion. (Five-sevenths natural size.)

The tissue composing hypoplastic organs or parts of organs, though of less bulk than normal, may present no abnormalities of structure. In other cases there may be associated with the smallness of size a disturbance of internal **organization**, so that often the more highly specialized elements of the organ fail of development, the *hypoplasia being at the same time associated with an agenesis of individual parts*. Thus, for example, in hypoplasia of the ovary (Fig. 45, *e*) the development of the ova and the ripening of the follicles may fail in part; in hypoplasia of the brain there may occur at the same time a defective development of the gan-



FIG. 45.—Cross sections of ovaries at different periods of life. (Hæmatoxylin and eosin.) *a, b, c, d*, Normal ovaries; *a*, girl of five years; *b*, twenty-three years; *c*, twenty-nine years; and *d*, twenty-one years; *e*, hypoplastic ovary of girl of twenty-seven years; *f, g*, senile ovaries from women of eighty and eighty-three years of age. (Natural size.)

glion-cells and nerve-fibres, and at times portions of the brain may consist only of membranous masses (Fig. 42, *d*) in which no ganglion-cells are present. In hypoplasia of the lung there may be under certain conditions a complete failure of development of the alveoli, so that the lung-tissue consists merely of a very vascular connective tissue throughout which lie the bronchi, the latter in the course of time usually becoming dilated.

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#### (*Hypoplasia and Agenesis.*)

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 See also Chapter IX.

§ 53. **Atrophy** is a diminution in the size of an organ due either diminution in size or disappearance of its individual elements. It occurs at any period of life, and is a very common result of many ological processes. Within certain limits it may be regarded as a *ological phenomenon*, in that in old age there constantly occurs a degree of retrograde change in all the organs, associated with a diminution in their size. Certain organs undergo such an atrophy with or total loss of their functional power, even before old age, as, for example, the thymus, which atrophies completely even before the end of the period of growth; and the ovary (Fig. 45, *f, g*), a part of whose function is discharged during the period of sexual activity, the remainder

destroyed. In old age the lymphadenoid tissues, the muscles and bones, in particular, suffer atrophy, though the tissue-changes of senility vary greatly in different individuals, so that often other tissues, the glandular organs or the brain, show the most marked atrophy.

The atrophy of an organ is characterized chiefly by its diminution in size. In atrophic conditions of the muscles (Fig. 46) the affected portions of the body become smaller, and in extreme cases the extremities appear as if consisting only of skin and bones. When the atrophy of an organ is uniform throughout, its normal shape may be preserved; but if the atrophy progresses more rapidly in certain parts than in others, the surface of the organ may show local depressions (Fig. 48) and cicatricial contractions (Fig. 51), so that the organ, for example, the liver or kidney, may present a knobbed or granular appearance. When tissues which are undergoing atrophy are prevented from contracting, as in the case of the bones and lungs, the external form is preserved. In the case of bone, the medullary spaces and the Haversian canals become enlarged, and a condition results which is known as *excentric atrophy* or *osteoporosis* (Fig. 47). In the lungs the alveoli become confluent into large air-spaces as the result of the disappearance of the intervening walls.

In atrophy of the glands and muscles there occurs frequently a change of color, though this is of secondary importance. Either the normal pigmentation of the affected organ is brought out more distinctly by its atrophy, or associated with the atrophy there is a deposit of pigment (brown or pigment atrophy), or finally the change of color may be dependent upon the changed blood-content of the atrophic tissue.

The diminution in size of atrophic organs is the result of a diminution in size and disappearance of the histological elements composing them. In the majority of the organs, particularly in the glands, muscles, and bones, the specific cells which perform the especial function of the affected organ, are affected in atrophy to a far greater degree than the supporting connective-tissue framework. Indeed, it may be frequently observed that the connective-tissue elements may be wholly preserved, or even increased in number, while the more highly specialized elements have disappeared. Thus, for example, in atrophic muscle (Fig. 49) the contractile substance within the sarcolemma (*a*) may disappear to a very great extent (*b*) without the occurrence of any atrophy whatever of the connective tissue between the muscle-bundles. The nuclei (*c*) of the connective tissue may even be increased in number.



FIG. 46.—Juvenile muscular atrophy. (Case observed by de Souza.)



In atrophy of the kidney the epithelial cells of the urinary tubules (Fig. 50, *f*) become smaller and may finally wholly vanish so that the tubules collapse. Likewise, the epithelium of the glomeruli (*d*) is lost, while the capillaries become obliterated.

The same thing occurs in simple atrophy of the liver, in that all the liver-cells of a lobule may disappear without any perceptible decrease of the supporting reticulum. Likewise the ganglion cells of the brain and spinal cord may atrophy without the neuroglia being diminished. Not infrequently the latter may become increased.

In atrophy of the bones the true bone-tissue becomes diminished, while the bone-marrow in excentric atrophy and osteoporosis becomes increased. Moreover the fat in the cells of the marrow may also vanish, so that free spaces are formed which become filled with fluid.

In atrophy of the lymph-glands and of the spleen the free cells in particular disappear and in parts are completely absent.

The changes leading to atrophy may take place without the occurrence of any apparent change of structure in the individual tissue-elements (Fig. 49), so that the condition of atrophy is reached essentially through a loss of volume of the individual parts. Both the cell-body and the nucleus may become smaller; and the latter change may be observed particularly in the liver in cases of starvation-atrophy (Lukjanow). This form of atrophy is known as **simple atrophy**, and is to be distinguished from the **degenerative atrophies**, in which the *tissue-elements during the progress of the atrophy show changes in their structure*, and frequently



FIG. 47.—Excentric atrophy of the lower end of the tibia and fibula, with osteoporosis. (Natural size.)

contain pathological substances. Thus a cell may become granular, and undergo fragmentation, or may swell up and liquefy, or there may be formed within the cell drops of fat or mucus; all of these changes signifying degenerative conditions of the cell-protoplasm. These processes are classed as special *forms of degeneration* and will be discussed in the paragraphs of the following section. Degenerative changes can occur at the same time in the nuclei, as shown by fragmentation, distorted shape, clumping of the chromatin, diffusion of chromatin into the cell-protoplasm, swelling and liquefaction of the nucleus.

All these processes lead ultimately to the disappearance of the nucleus and the destruction of the cell.

The degenerations leading ultimately to a condition of atrophy of the affected organ are of very frequent occurrence, particularly in glandular

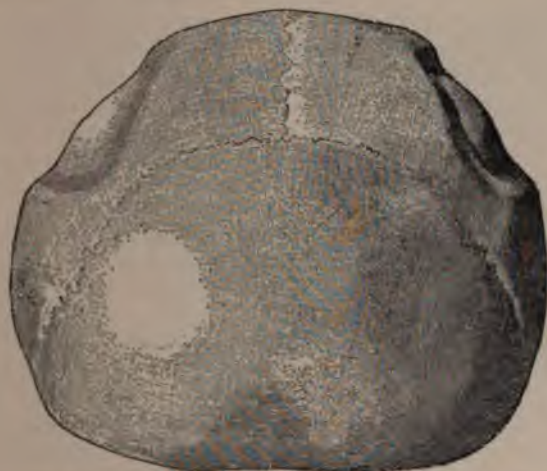


FIG. 48.—Senile atrophy of the skull-cap, with defect of the external table and the spongy portion throughout the central portion of both parietal bones.

organs. The process is often complicated by the occurrence of inflammation.

According to their genesis the **forms of atrophy** may be classed as **active or passive**. In the former the cell is no longer able to make use of the food brought to it; in the latter the food is either not supplied to the cell in sufficient quantity or in the proper form, or harmful substances are brought to the cells which impair their function. Active

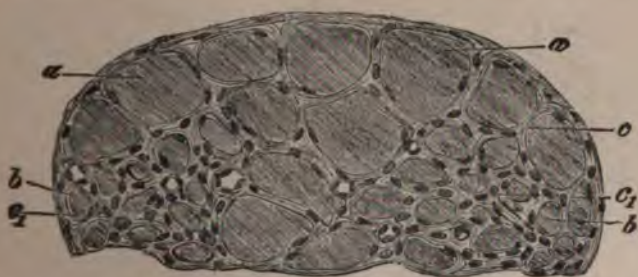


FIG. 49.—Section of an atrophic muscle, from a case of progressive muscular atrophy. (Müller's fluid, Bismarck brown.) *a*, Normal muscle-fibres; *b*, atrophic muscle-fibres; *c*, perimysium internum, the nuclei of which, at *c*<sub>1</sub>, seem to be increased in number.  $\times 200$ .

atrophy is particularly a part of *senile degeneration* (see above), but it occurs also under pathological conditions, especially in the case of nerves, glands, and muscles (Fig. 46) whose functional activity is not called into play.

The clinician ordinarily prefers another classification of atrophy;



namely, senile atrophy, atrophy due to impaired nutrition, pressure atrophy, atrophy of disuse, and neuropathic atrophy.

**Senile atrophy** (Fig. 48) is partly active, and partly passive, in that it is not simply the result of the diminishing vital energy of the cell, but also depends in part upon the narrowing and obliteration of the vessels conveying nourishment to the cells. It may occur in all the organs, but is often more marked in one organ than in another. The bones, kidneys, liver, brain, and heart may undergo a marked loss of volume.



FIG. 50.—Senile atrophy of the kidney. (Alcohol, alum-carbaine.) *a*, Normal urinary tubules; *b*, normal glomerulus; *c*, stroma with blood-vessels; *d*, atrophic and obliterated glomerulus; *e*, small artery, with thickened intima; *f*, atrophic and collapsed urinary tubules.  $\times 200$ .

**Atrophy due to impaired nutrition** may result in the first place from an insufficient supply of food to the body as a whole, or from extensive loss of the fluids of the body. In these cases the whole body is affected, though the fat, blood, muscles, and the abdominal organs suffer to a greater extent than the re-

maining tissues. Local atrophies may result from local disturbances of circulation (Fig. 51), and are the frequent sequelæ of *diseases of the blood-vessels*. Further, they are of frequent occurrence as a result or a part of inflammatory processes; but it should be noted, that in these cases the condition is not of the nature of a simple atrophy, but rather of various *degenerative changes* leading to the death of the cells and of the tissues.

At times atrophy results from the presence of deleterious substances in the blood. For example, iodine causes a diminution in the size of the



FIG. 51.—Arteriosclerotic atrophy of the kidney. (Natural size.)

thyroid gland. In chronic lead-poisoning the extensor muscles of the forearm in particular become atrophic.

**Pressure-atrophy** occurs when a tissue is subjected for a length of time to a moderate pressure (Fig. 52). It depends partly upon direct injury to the tissues and partly upon disturbance of the circulation. The most typical examples are: the atrophy of the liver caused by the

pressure of the edge of the ribs upon the organ due to tight-lacing ("cor-set-liver"), and the disappearance of bone (Fig. 52) following the pressure of an aortic aneurism, tumors, or of an accumulation of fluid in the ventricles of the brain.

**Atrophy of disuse** occurs in the muscles, glands, bones, skin, and other tissues, and is dependent upon the disuse of the organ in question. In the case of muscles and glands the atrophy is essentially active; the nutritive processes diminishing as the result of the lessened functional activity; moreover, the consequent diminution of the circulation through the part is not without effect. In the other tissues the atrophy is essentially dependent upon the lowering of nutrition of the disused parts, though a change in the power of assimilation of the cells cannot be wholly excluded. When the inactivity occurs during the period of development, and the tissue as a result becomes stunted, the condition is to be regarded as a hypoplasia, though no sharp line can be drawn between hypoplasia and atrophy, since in the former there may be also a disappearance of structures which had undergone a certain degree of development.

**Neuropathic atrophy** is a result of diseased conditions of the nervous system, and is apparent most often in a rapid atrophy of the nerves and muscles, though other tissues may be affected.

For example, after destruction of the anterior horns or of the motor roots of the spinal cord, there follows an atrophy of the corresponding nerves and muscles. After injury of the peripheral nerves the skin often becomes atrophic. According to many authors, disease of the nerve-trunks of one side of the face is followed by a *unilateral neuropathic facial atrophy* (Fig. 53), but by others (Möbius) the neuropathic nature of this condition is contested. Unilateral affections of the brain in foetal life or during childhood may lead to atrophy of the opposite side of the body (*congenital and infantile hemiatrophy*).



FIG. 52.—Pressure-atrophy of the spinal column, due to pressure by aortic aneurism.



FIG. 53.—Facial hemiatrophy. (After Lichtheim and Borel.)



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## V. Cloudy Swelling and Hydropic Degeneration.

§ 54. The term **cloudy swelling** or *parenchymatous degeneration* or *granular degeneration* is applied to that form of cell-degeneration which is characterized histologically by a swelling and enlargement of the cells



FIG. 54.—Cloudy swelling of liver-cells (scraping from the cut surface of the liver of a man dying of septicæmia, examined in normal salt solution.)  $\times 350$ .

due to the formation within the cell-protoplasm of free granules, which according to their microchemical properties (solubility in acetic acid, insolubility in alkalies and ether) are to be regarded as albuminous bodies. The epithelial cells of the kidney and liver (Fig. 54), and the cells of heart-muscle frequently show this degeneration, thereby acquiring a cloudy appearance, as if covered with dust, while at the same time their normal structure and form are lost. Thus, for example, in cloudy swelling of the kidney-epithelium the rod-like markings of the protoplasm are lost (Fig. 55, *a*), as are also the cell-processes projecting into the lumen of the tubules. The swollen cells (*b*, *c*, *d*) are larger, more plump, and contain dark granules. This change is to be regarded as a *disorganization of the protoplasm* following an absorption

of fluid, and leads to partial separation of the solid and liquid constituents of the protoplasm. At the same time the *nucleus swells and undergoes disorganization*.

Recovery is possible at a certain degree, and the cells may be restored to their normal condition. In other cases the cell-body is de-

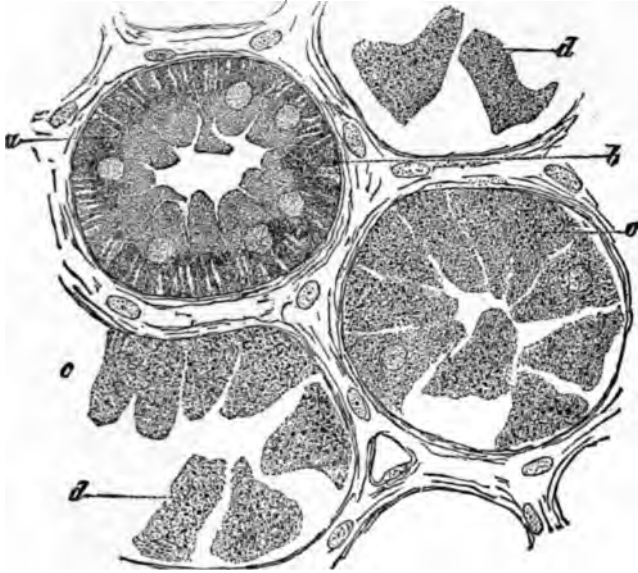


FIG. 55.—Cloudy swelling of kidney epithelium. (Chromic acid, ammonia, glycerin.) *a*, Normal epithelium; *b*, beginning cloudy swelling; *c*, advanced stage of cloudy swelling; *d*, desquamated degenerated epithelium.  $\times 600$ .

stroyed, breaking up into granular fragments. Fatty degeneration very often accompanies cloudy swelling.

Cloudy swelling may occur in the cells of any of the parenchymatous organs, as the liver, kidneys, or heart, during the course of the majority of the infectious diseases, particularly in scarlet fever, typhoid, small-pox, erysipelas, diphtheria, septicæmia, etc. The affected organs present a cloudy, dull-shining, often gray appearance; in marked cases the organ may appear as if cooked, the blood-content is very slight, the consistency doughy, and the finer details of structure are lost.

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§ 55. **Hydropic degeneration** is that form of degeneration frequently observed in cells of different kinds, whereby they become swollen through

the imbibition of fluid.

When epithelial cells undergo this change the cell-contents appear clear, the granules of the protoplasm are pressed farther apart by the fluid, often being crowded into a ring at the periphery of the cell; the cells thus coming to resemble plant-cells to a certain extent. Vacuoles (Fig. 56, *b*)—that is, globules of clear fluid—may often be formed within the cells. The nucleus (*c*) also swells and becomes changed to a large bladder-like vacuole containing clear fluid. In muscles show-

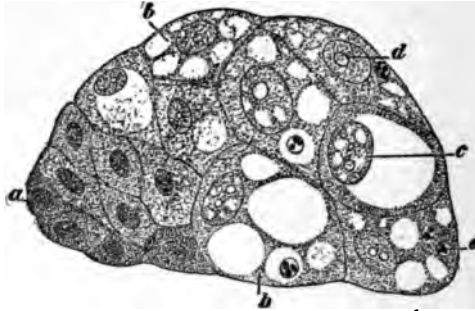


FIG. 56.—Hydropic degeneration of epithelial cells from a carcinoma of the breast. (Müller's fluid, aniline brown.) *a*, Unchanged epithelium; *b*, hydropic cells containing bladder-like drops of fluid [physalides]; *c*, hydropic nuclei; *d*, enlarged nuclei; *e*, wandering cells.  $\times 300$ .

ing hydropic degeneration clear droplets of fluid appear between the fibrillae, pushing the latter apart (Fig. 57, 58, *a*, *b*, and Fig. 66, *c*). Through an abundant formation of such drops the muscle fibres may acquire in places an appearance of foam-like bubbles (Fig. 57). At first, the muscle fibres between these drops remain preserved, but finally they undergo fragmentation and liquefaction.

Hydropic degeneration of cells may be the result of cedema (Figs. 57 and 58); it occurs also in inflammatory foci (Fig. 66) and in tumor-

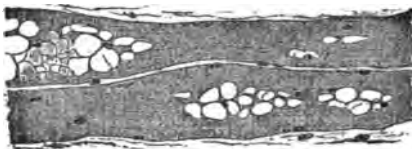


FIG. 57.—Hydropic degeneration of muscle-fibres from the calf muscle in chronic cedema of the leg. (Flemming's solution, safranin.)  $\times 45$ .



FIG. 58.—Transverse section of a muscle-bundle showing hydropic degeneration of its fibres. (Müller's fluid, haematoxylin.) *a*, Muscle-fibre with small drops of fluid; *b*, muscle-fibre with large drops.  $\times 60$ .

cells (Fig. 56). In the case of inflammation the degenerative character of the process is more marked than in the case of cedema; and a complete liquefaction of the cells and nuclei may result. In cedema the cells, in spite of their hydropic condition, may remain alive for a long time.

## VI. Lipomatosis, Atrophy of Fat-Tissue and Fatty Degeneration.

§ 56. Certain tissues of the human body contain normally a certain amount of fat, which deposited in cells is heaped up in such amounts as

to be easily recognizable by the naked eye. This fat is a **deposit** which arises either from the fat ingested, or from fat formed within the body out of albumin and carbohydrates and then deposited in the tissues.

If the amount of fat taken in or produced within the body is abnormally great, or if the organism is not able to make proper use of the fat ingested or elaborated in the tissues, there arises a disturbance of the balance between fat-production and fat-consumption, in favor of the first, so that there results an increase in the storing-up of fat. This may finally reach such a degree that the functions of the organs concerned may be impaired, and the condition must therefore be regarded as pathological. Such an excessive accumulation of fat is designated **obesity** or *adipositas* or *lipomatosis*.

The **increased deposit of fat** occurs first in the normal fat-depôts, the panniculus of the skin and serous membranes, the bone-marrow, and



FIG. 59.—Fatty liver from a case of pulmonary tuberculosis. (Flemming's solution, safranin.) *a*, Central portion of the liver-lobule; *b*, peripheral zone containing fat; *c*, periportal connective tissue.  $\times 30$ .

under certain conditions also in the liver (Fig. 59, *b*). Later the fat is deposited in places which normally contain none, as for example, in the connective tissue between the muscle-fibres of the heart, in the endocardium of the ventricles and auricles, and in the intermuscular connective tissue of the skeletal muscles (Fig. 60), etc.

In connective-tissue cells and in liver-cells the fat is deposited in the form of small droplets (Fig. 62, *a*, *b*), which usually soon coalesce to form larger drops, so that the cells become changed into globular masses of fat.

The **pathological deposit** of fat may be due either to a congenital predisposition or to especial pathological conditions of life. *Lipomatosis due to a congenital predisposition* may be manifested as a *general obesity*, in which the fat throughout the entire body is increased, or the increase may be confined to certain areas. In the latter case (the tumor-like accumulations of fat being excepted) the excessive deposit of fat is most frequently localized in the *muscles* of the lower extremities (Fig. 60), which thereby increase in volume, but at the same time lose a part of their fibres (*atrophia musculorum lipomatosa pseudohypertrophica*).

Among the conditions of life which lead to a pathological accumulation of fat are: first, a *luxurious mode of living*; further, *wasting of bodily strength*, and *marasmus*, such as is observed especially in chronic tuberculosis. In

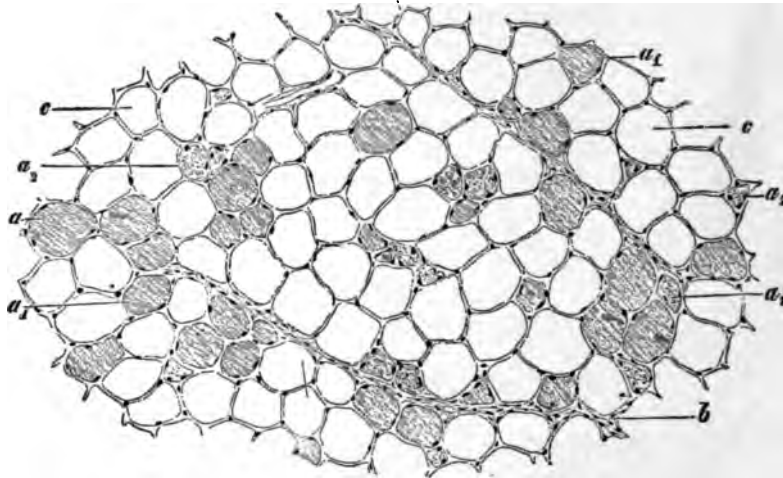


FIG. 60.—Lipomatosis of the calf muscles, associated with atrophy. (Müller's fluid, carmine.) *a*, Transverse section of normal fibre; *a*<sub>1</sub>, of atrophic fibre; *a*<sub>2</sub>, transverse section of sarcolemma tube containing disintegrated contractile substance; *b*, connective tissue; *c*, fat-tissue.  $\times 60$ .

the first case the deposit of fat is a general one. In the last, the accumulation of fat is usually confined to the liver (Fig. 59), the liver-tissue at the seat of deposit becoming clear yellowish-gray to a straw-yellow in color. In the first case the cause of the fat-deposit is the excess of nutri-

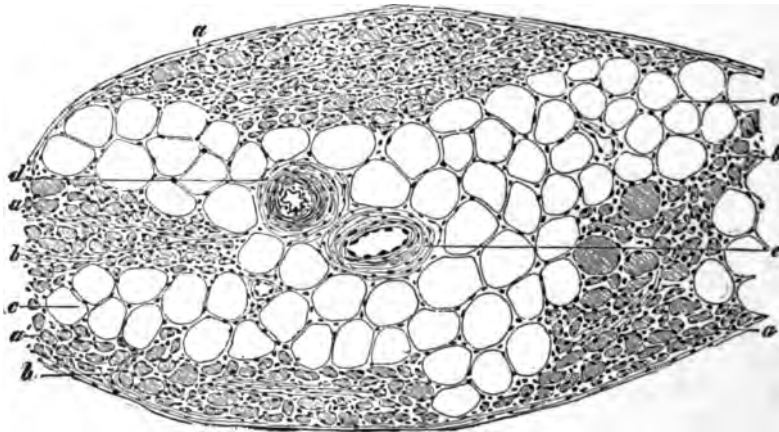


FIG. 61.—Spinal muscular atrophy with lipomatosis, in ascending atrophy of the anterior horns of the spinal cord. (Müller's fluid, Bismarck brown.) Section from the calf muscle. *a*, Transverse section of atrophic muscle-fibres; *b*, perimysium; *c*, fat-tissue; *d*, artery; *e*, vein.  $\times 60$ .

tive material ingested; in the last case it is the inability of the organism to use up in sufficient measure the fat taken in or elaborated within the body.



Under certain conditions a more marked *local fat-deposit* may occur as a sequela to tissue atrophy, as, for example, in the neighborhood of contracted kidneys, and in muscles (Fig. 61, c), which suffer a progressive atrophy (a), as the result of diseases of the spinal cord.

If through a diminution in the amount of nourishment taken into the body, or through a deficient formation of fat within the body, or through an increased metabolism, the normal amount of body-fat is lost, the condition is known as **atrophy of the fat-tissue**. In the process of absorption and decomposition of the fat, the latter becomes broken up into small droplets, and the fat-cells are finally converted into small connective-tissue cells. If, after the disappearance of the fat the spaces between the shrunken fat-cells become filled with a serous fluid, the fat-tissue acquires a translucent appearance similar to that of myxomatous tissue; and this condition, which occurs especially often in the panniculus of the heart, is designated *serous atrophy of the fat-tissue*. Occasionally pigment may be deposited in the atrophic fat-cells, so that the tissue acquires a yellow or yellowish-brown color. This condition is designated *yellow atrophy of fat-tissue*.

The fat deposited in the body may, in the first place, arise from that ingested, so that in dogs fed with mutton-fat there occurs a deposit of mutton-fat (*Rosenfeld*), and the feeding of iodized fat leads also to a deposit of iodized fat in the fat-depôts (*Winternitz*). It is ordinarily assumed, particularly with reference to the fat-droplets in the chyle, that such fat, finely emulsified, is taken up through openings in the cuticular margin of the epithelium of the intestinal mucosa. Against this view is opposed the fact that such an absorption of fat by the intestinal epithelium cannot be followed step by step. *Flemming*, therefore, assumes that, in the case of the absorption of fat from the intestine, as well as its entrance into the fat-cells, the *elements of the fat are taken up by the cells in the form of soluble combinations*, and are converted in the cells by the chemical activity of their protoplasm again into fat; and that, further, in atrophy of fat-tissue, the *fat is chemically split up into soluble combinations and so passed out of the cells*. According to *Connstein*, the absorbable fats in the stomach and intestine are for the greater part split up; and, through the combination of the fatty acids with the alkalies present in the intestine, are converted into soluble soaps which are absorbed by the epithelium. These soaps are changed in the intestinal epithelium (in the same way that the absorbed peptone is again changed to an albuminate) back again to globules of neutral fat. The glycerin necessary for this process is absorbed directly from the intestine where it is present in the free state, having been split off from the neutral fats.

Besides that formed from fat and fatty acids, the organism can also form and store up fats from carbohydrates and albumin. The formation of fat from albumin is denied by various authors (*Pflüger*), but has been established beyond any doubt by different observations (see *Lindemann, l.c.*).

According to *Voit*, the immediate factor in metabolism is not the action of oxygen, but lies in the organization of the cells, the protoplasm of which possesses the power, in proportion to the external conditions, to break down complex chemical combinations into simpler ones. The albumin brought to the cell in a soluble form, and after this the carbohydrates are the most easily decomposed by the cells, fat with greater difficulty, either that taken in with the food or formed within the body from albumin or carbohydrates. When fat is supplied in excess, or when the activity of the cells is exhausted before the fat split off from albumin is further decomposed, there will occur a deposit of fat. The same thing will happen when fat and carbohydrates or albumin are supplied at the same time, if the cells after decomposing the latter are incapable of further activity. Increase of food-supply, muscular action, and elevation of body-temperature cause an increase in the metabolic activity of the cells, while alcohol, morphine, and quinine weaken it. Obesity depends upon a greater assimilation of food than can be used by the body. The metabolism in this condition may either be normal, or may be diminished through weakness of the cells or diminution of their number. The cause of the increased deposit of fat in anæmic conditions may be explained by the diminution of the cell-mass of the body and the consequent weakening of metabolism. The deposit of fat in the cells of the intermuscular connective tissue of atrophic muscle may be regarded as due to diminished metabolism in the muscle.

According to *Gautier*, the decomposition of albumin in the cells is the result of their functional activity, and occurs in two phases. In the first, the phase of ferment-

action without oxidation, or hydrolytic splitting, there are formed from the protoplasm urea or analogous combinations (salts of uric acid, kreatin-bodies), and at the same time the carbohydrates form the fat-bodies. In the second, the phase of oxidation, the sugar and fat disappear, both that formed from albumin and that derived from the ingested food. The carbohydrates are in part oxidized; but the greater part, especially during muscular inactivity, are changed into fat through a simple process of fermentation, by which a large amount of carbonic acid is set free. Finally, the fat-bodies are also oxidized and disappear.

### Literature.

#### (The Pathology of Adipose Tissue.)

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§ 57. **Fatty degeneration** is that form of cell-degeneration in which fat is formed from the albumin of the cell-body—that is, from the albumin of the organism—and appears within the cell in the form of granules, droplets, or drops. **Cells which are in the condition of fatty degeneration** present within their cell-substance

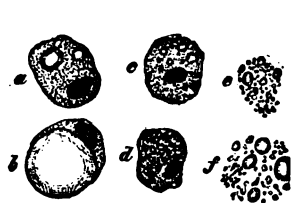


FIG. 62.—Fat-containing liver-cells. a and b, Fat-infiltration; c, d, c, f, fatty degeneration.  $\times 400$ .



FIG. 63.—Fatty degeneration of the heart-muscle.  $\times 350$ .

**small or larger droplets**, which are clear, and highly refractive (Fig. 62, a, d, e, f, and Fig. 63), insoluble in acetic acid, and soluble in alcohol and ether. With osmic acid they become black (Fig. 64, b and Fig. 65, A, B, C); in

All these processes lead ultimately to the disappearance of the nucleus and the destruction of the cell.

The degenerations leading ultimately to a condition of atrophy of the affected organ are of very frequent occurrence, particularly in glandular

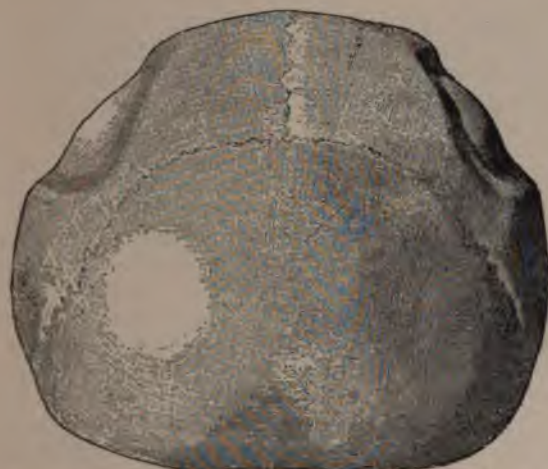


FIG. 48.—Senile atrophy of the skull-cap, with defect of the external table and the spongy portion throughout the central portion of both parietal bones.

organs. The process is often complicated by the occurrence of inflammation.

According to their genesis the forms of atrophy may be classed as **active** or **passive**. In the former the cell is no longer able to make use of the food brought to it; in the latter the food is either not supplied to the cell in sufficient quantity or in the proper form, or harmful substances are brought to the cells which impair their function. Active

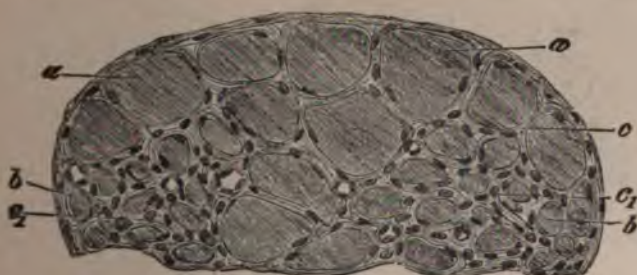


FIG. 49.—Section of an atrophic muscle, from a case of progressive muscular atrophy. (Müller's fluid, Biernacki brown.) *a*, Normal muscle-fibres; *b*, atrophic muscle-fibres; *c*, perimysium internum, the nuclei of which, at *c*<sub>1</sub>, seem to be increased in number.  $\times 200$ .

atrophy is particularly a part of *senile degeneration* (see above), but it occurs also under pathological conditions, especially in the case of nerves, glands, and muscles (Fig. 46) whose functional activity is not called into play.

The clinician ordinarily prefers another classification of atrophy;



namely, senile atrophy, atrophy due to impaired nutrition, pressure atrophy, atrophy of disuse, and neuropathic atrophy.

**Senile atrophy** (Fig. 48) is partly active, and partly passive, in that it is not simply the result of the diminishing vital energy of the cell, but also depends in part upon the narrowing and obliteration of the vessels conveying nourishment to the cells. It may occur in all the organs, but is often more marked in one organ than in another. The bones, kidneys, liver, brain, and heart may undergo a marked loss of volume.



FIG. 50.—Senile atrophy of the kidney. (Alcohol, alum-carmine.) *a*, Normal urinary tubules; *b*, normal glomerulus; *c*, stroma with blood-vessels; *d*, atrophic and obliterated glomerulus; *e*, small artery, with thickened intima; *f*, atrophic and collapsed urinary tubules.  $\times 200$ .

**Atrophy due to impaired nutrition** may result in the first place from an insufficient supply of food to the body as a whole, or from extensive loss of the fluids of the body. In these cases the whole body is affected, though the fat, blood, muscles, and the abdominal organs suffer to a greater extent than the re-

maining tissues. Local atrophies may result from local disturbances of circulation (Fig. 51), and are the frequent sequelæ of *diseases of the blood-vessels*. Further, they are of frequent occurrence as a result or a part of inflammatory processes; but it should be noted, that in these cases the condition is not of the nature of a simple atrophy, but rather of various *degenerative changes* leading to the death of the cells and of the tissues.

At times atrophy results from the presence of deleterious substances in the blood. For example, iodine causes a diminution in the size of the



FIG. 51.—Arteriosclerotic atrophy of the kidney. (Natural size.)

thyroid gland. In chronic lead-poisoning the extensor muscles of the forearm in particular become atrophic.

**Pressure-atrophy** occurs when a tissue is subjected for a length of time to a moderate pressure (Fig. 52). It depends partly upon direct injury to the tissues and partly upon disturbance of the circulation. The most typical examples are: the atrophy of the liver caused by the

pressure of the edge of the ribs upon the organ due to tight-lacing ("cor-set-liver"), and the disappearance of bone (Fig. 52) following the pressure of an aortic aneurism, tumors, or of an accumulation of fluid in the ventricles of the brain.

**Atrophy of disuse** occurs in the muscles, glands, bones, skin, and other tissues, and is dependent upon the disuse of the organ in question. In the case of muscles and glands the atrophy is essentially active; the nutritive processes diminishing as the result of the lessened functional activity; moreover, the consequent diminution of the circulation through the part is not without effect. In the other tissues the atrophy is essentially dependent upon the lowering of nutrition of the disused parts, though a change in the power of assimilation of the cells cannot be wholly excluded. When the inactivity occurs during the period of development, and the tissue as a result becomes stunted, the condition is to be regarded as a hypoplasia, though no sharp line can be drawn between hypoplasia and atrophy, since in the former there may be also a disappearance of structures which had undergone a certain degree of development.

**Neuropathic atrophy** is a result of diseased conditions of the nervous system, and is apparent most often in a rapid atrophy of the nerves and muscles, though other tissues may be affected.

For example, after destruction of the anterior horns or of the motor roots of the spinal cord, there follows an atrophy of the corresponding nerves and muscles. After injury of the peripheral nerves the skin often becomes atrophic. According to many authors, disease of the nerve-trunks of one side of the face is followed by a *unilateral neuropathic facial atrophy* (Fig. 53), but by others (Möbius) the neuropathic nature of this condition is contested. Unilateral affections of the brain in fetal life or during childhood may lead to atrophy of the opposite side of the body (*congenital and infantile hemiatrophy*).



FIG. 52.—Pressure-atrophy of the spinal column, due to pressure by aortic aneurism.



FIG. 53.—Facial hemiatrophy. (After Lichthelm and Borel.)

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- See also § 23.

## V. Cloudy Swelling and Hydropic Degeneration.

§ 54. The term **cloudy swelling** or *parenchymatous degeneration* or *granular degeneration* is applied to that form of cell-degeneration which is characterized histologically by a swelling and enlargement of the cells



FIG. 54.—Cloudy swelling of liver-cells (scraping from the cut surface of the liver of a man dying of septicæmia, examined in normal salt solution.)  $\times 350$ .

due to the formation within the cell-protoplasm of free granules, which according to their microchemical properties (solubility in acetic acid, insolubility in alkalies and ether) are to be regarded as albuminous bodies. The epithelial cells of the kidney and liver (Fig. 54), and the cells of heart-muscle frequently show this degeneration, thereby acquiring a cloudy appearance, as if covered with dust, while at the same time their normal structure and form are lost. Thus, for example, in cloudy swelling of the kidney-epithelium the rod-like markings of the protoplasm are lost (Fig. 55, a), as are also the cell-processes projecting into the lumen of the tubules. The swollen cells (b, c, d) are larger, more plump, and contain dark granules. This change is to be regarded as a *disorganization of the protoplasm* following an absorption

of fluid, and leads to partial separation of the solid and liquid constituents of the protoplasm. At the same time the *nucleus swells and undergoes disorganization*.

Recovery is possible at a certain degree, and the cells may be restored to their normal condition. In other cases the cell-body is de-

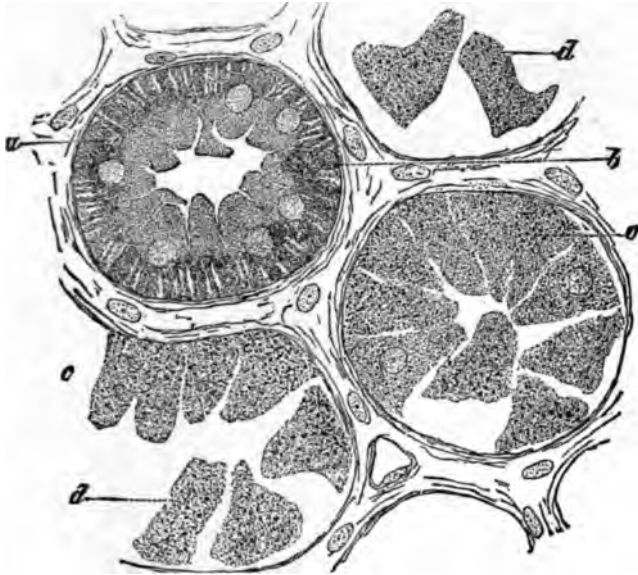


FIG. 55.—Cloudy swelling of kidney epithelium. (Chromic acid, ammonia, glycerin.) *a*, Normal epithelium; *b*, beginning cloudy swelling; *c*, advanced stage of cloudy swelling; *d*, desquamated degenerated epithelium.  $\times 600$ .

stroyed, breaking up into granular fragments. Fatty degeneration very often accompanies cloudy swelling.

Cloudy swelling may occur in the cells of any of the parenchymatous organs, as the liver, kidneys, or heart, during the course of the majority of the infectious diseases, particularly in scarlet fever, typhoid, small-pox, erysipelas, diphtheria, septicæmia, etc. The affected organs present a cloudy, dull-shining, often gray appearance; in marked cases the organ may appear as if cooked, the blood-content is very slight, the consistency doughy, and the finer details of structure are lost.

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§ 55. **Hydropic degeneration** is that form of degeneration frequently observed in cells of different kinds, whereby they become swollen through

the imbibition of fluid.

When epithelial cells undergo this change the cell-contents appear clear, the granules of the protoplasm are pressed farther apart by the fluid, often being crowded into a ring at the periphery of the cell; the cells thus coming to resemble plant-cells to a certain extent. Vacuoles (Fig. 56, *b*)—that is, globules of clear fluid—may often be formed within the cells. The nucleus (*c*) also swells and becomes changed to a large bladder-like vacuole containing clear fluid. In muscles show-

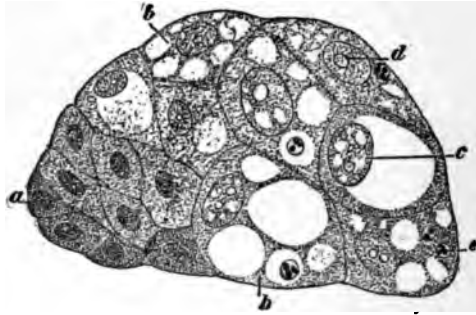


FIG. 56.—Hydropic degeneration of epithelial cells from a carcinoma of the breast. (Müller's fluid, aniline brown.) *a*, Unchanged epithelium; *b*, hydropic cells containing bladder-like drops of fluid [physalides]; *c*, hydropic nuclei; *d*, enlarged nucleoli; *e*, wandering cells.  $\times 300$ .

ing hydropic degeneration clear droplets of fluid appear between the fibrillae, pushing the latter apart (Fig. 57, 58, *a*, *b*, and Fig. 66, *c*). Through an abundant formation of such drops the muscle fibres may acquire in places an appearance of foam-like bubbles (Fig. 57). At first, the muscle fibres between these drops remain preserved, but finally they undergo fragmentation and liquefaction.

Hydropic degeneration of cells may be the result of œdema (Figs. 57 and 58); it occurs also in inflammatory foci (Fig. 66) and in tumor-

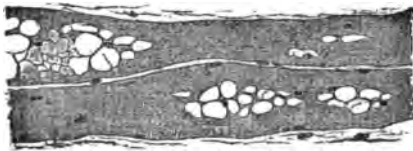


FIG. 57.—Hydropic degeneration of muscle-fibres from the calf muscle in chronic œdema of the leg. (Flemming's solution, safranin.)  $\times 45$ .

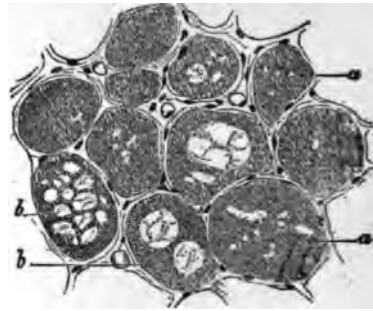


FIG. 58.—Transverse section of a muscle-bundle showing hydropic degeneration of its fibres. (Müller's fluid, hæmatoxylin.) *a*, Muscle-fibre with small drops of fluid; *b*, muscle-fibre with large drops.  $\times 66$ .

cells (Fig. 56). In the case of inflammation the degenerative character of the process is more marked than in the case of œdema; and a complete liquefaction of the cells and nuclei may result. In œdema the cells, in spite of their hydropic condition, may remain alive for a long time.

## VI. Lipomatosis, Atrophy of Fat-Tissue and Fatty Degeneration.

§ 56. Certain tissues of the human body contain normally a certain amount of fat, which deposited in cells is heaped up in such amounts as



to be easily recognizable by the naked eye. This fat is a **deposit** which arises either from the fat ingested, or from fat formed within the body out of albumin and carbohydrates and then deposited in the tissues.

If the amount of fat taken in or produced within the body is abnormally great, or if the organism is not able to make proper use of the fat ingested or elaborated in the tissues, there arises a disturbance of the balance between fat-production and fat-consumption, in favor of the first, so that there results an increase in the storing-up of fat. This may finally reach such a degree that the functions of the organs concerned may be impaired, and the condition must therefore be regarded as pathological. Such an excessive accumulation of fat is designated **obesity** or *adipositas* or *lipomatosis*.

The **increased deposit of fat** occurs first in the normal fat-depôts, the panniculus of the skin and serous membranes, the bone-marrow, and

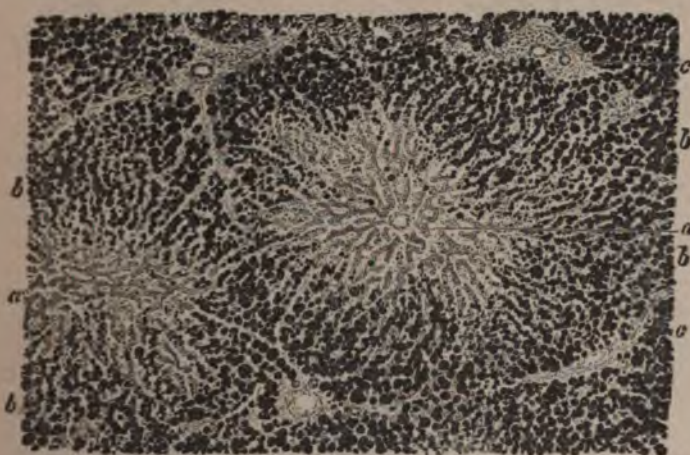


FIG. 59.—Fatty liver from a case of pulmonary tuberculosis. (Flemming's solution, safranin.) *a*, Central portion of the liver-lobule; *b*, peripheral zone containing fat; *c*, periportal connective tissue.  $\times 30$ .

under certain conditions also in the liver (Fig. 59, *b*). Later the fat is deposited in places which normally contain none, as for example, in the connective tissue between the muscle-fibres of the heart, in the endocardium of the ventricles and auricles, and in the intermuscular connective tissue of the skeletal muscles (Fig. 60), etc.

In connective-tissue cells and in liver-cells the fat is deposited in the form of small droplets (Fig. 62, *a*, *b*), which usually soon coalesce to form larger drops, so that the cells become changed into globular masses of fat.

The **pathological deposit** of fat may be due either to a congenital predisposition or to especial pathological conditions of life. *Lipomatosis due to a congenital predisposition* may be manifested as a *general obesity*, in which the fat throughout the entire body is increased, or the increase may be confined to certain areas. In the latter case (the tumor-like accumulations of fat being excepted) the excessive deposit of fat is most frequently localized in the *muscles* of the lower extremities (Fig. 60), which thereby increase in volume, but at the same time lose a part of their fibres (*atrophia musculorum lipomatosa pseudohypertrophica*).

Among the *conditions of life which lead to a pathological accumulation of fat* are: first, a *luxurious mode of living*; further, *wasting of bodily strength*, and *marasmus*, such as is observed especially in chronic tuberculosis. In

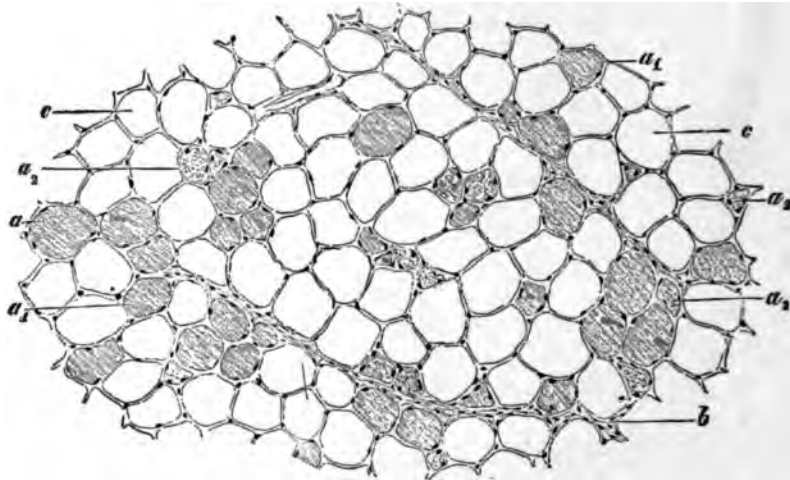


FIG. 60.—Lipomatosis of the calf muscles, associated with atrophy. (Müller's fluid, carmine.) *a*, Transverse section of normal fibre; *a*<sub>1</sub>, of atrophic fibre; *a*<sub>2</sub>, transverse section of sarcolemma tube containing disintegrated contractile substance; *b*, connective tissue; *c*, fat-tissue.  $\times 60$ .

the first case the deposit of fat is a general one. In the last, the accumulation of fat is usually confined to the liver (Fig. 59), the liver-tissue at the seat of deposit becoming clear yellowish-gray to a straw-yellow in color. In the first case the cause of the fat-deposit is the excess of nutri-

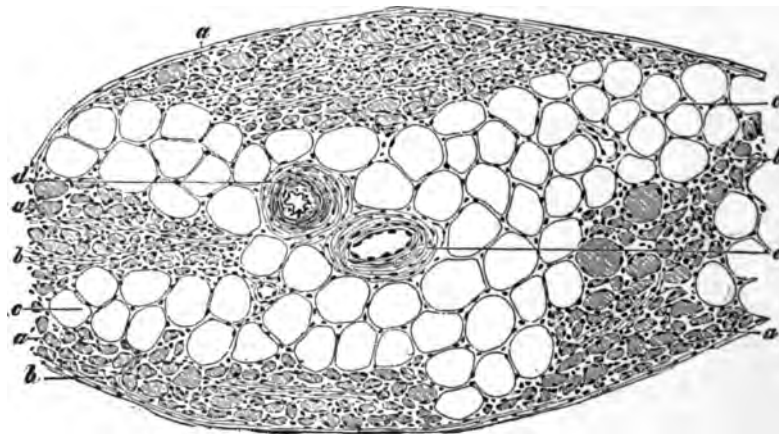


FIG. 61.—Spinal muscular atrophy with lipomatosis, in ascending atrophy of the anterior horns of the spinal cord. (Müller's fluid, Bismarck brown.) Section from the calf muscle. *a*, Transverse section of atrophic muscle-fibres; *b*, perimysium; *c*, fat-tissue; *d*, artery; *e*, vein.  $\times 60$ .

tive material ingested; in the last case it is the inability of the organism to use up in sufficient measure the fat taken in or elaborated within the body.

Under certain conditions a more marked *local fat-deposit* may occur as a sequela to tissue atrophy, as, for example, in the neighborhood of contracted kidneys, and in muscles (Fig. 61, c), which suffer a progressive atrophy ( $\alpha$ ), as the result of diseases of the spinal cord.

If through a diminution in the amount of nourishment taken into the body, or through a deficient formation of fat within the body, or through an increased metabolism, the normal amount of body-fat is lost, the condition is known as **atrophy of the fat-tissue**. In the process of absorption and decomposition of the fat, the latter becomes broken up into small droplets, and the fat-cells are finally converted into small connective-tissue cells. If, after the disappearance of the fat the spaces between the shrunken fat-cells become filled with a serous fluid, the fat-tissue acquires a translucent appearance similar to that of myxomatous tissue; and this condition, which occurs especially often in the panniculus of the heart, is designated *serous atrophy of the fat-tissue*. Occasionally pigment may be deposited in the atrophic fat-cells, so that the tissue acquires a yellow or yellowish-brown color. This condition is designated *yellow atrophy of fat-tissue*.

The fat deposited in the body may, in the first place, arise from that ingested, so that in dogs fed with mutton-fat there occurs a deposit of mutton-fat (*Rosenfeld*), and the feeding of iodized fat leads also to a deposit of iodized fat in the fat-depôts (*Winternitz*). It is ordinarily assumed, particularly with reference to the fat-droplets in the chyle, that such fat, finely emulsified, is taken up through openings in the cuticular margin of the epithelium of the intestinal mucosa. Against this view is opposed the fact that such an absorption of fat by the intestinal epithelium cannot be followed step by step. *Flemming*, therefore, assumes that, in the case of the absorption of fat from the intestine, as well as its entrance into the fat-cells, the *elements of the fat are taken up by the cells in the form of soluble combinations*, and are converted in the cells by the chemical activity of their protoplasm again into fat; and that, further, in atrophy of fat-tissue, the fat is *chemically split up into soluble combinations and so passed out of the cells*. According to *Connstein*, the absorbable fats in the stomach and intestine are for the greater part split up; and, through the combination of the fatty acids with the alkalis present in the intestine, are converted into soluble soaps which are absorbed by the epithelium. These soaps are changed in the intestinal epithelium (in the same way that the absorbed peptone is again changed to an albuminate) back again to globules of neutral fat. The glycerin necessary for this process is absorbed directly from the intestine where it is present in the free state, having been split off from the neutral fats.

Besides that formed from fat and fatty acids, the organism can also form and store up fats from carbohydrates and albumin. The formation of fat from albumin is denied by various authors (*Pflüger*), but has been established beyond any doubt by different observations (see *Lindemann, l.c.*).

According to *Voit*, the immediate factor in metabolism is not the action of oxygen, but lies in the organization of the cells, the protoplasm of which possesses the power, in proportion to the external conditions, to break down complex chemical combinations into simpler ones. The albumin brought to the cell in a soluble form, and after this the carbohydrates are the most easily decomposed by the cells, fat with greater difficulty, either that taken in with the food or formed within the body from albumin or carbohydrates. When fat is supplied in excess, or when the activity of the cells is exhausted before the fat split off from albumin is further decomposed, there will occur a deposit of fat. The same thing will happen when fat and carbohydrates or albumin are supplied at the same time, if the cells after decomposing the latter are incapable of further activity. Increase of food-supply, muscular action, and elevation of body-temperature cause an increase in the metabolic activity of the cells, while alcohol, morphine, and quinine weaken it. Obesity depends upon a greater assimilation of food than can be used by the body. The metabolism in this condition may either be normal, or may be diminished through weakness of the cells or diminution of their number. The cause of the increased deposit of fat in anæmic conditions may be explained by the diminution of the cell-mass of the body and the consequent weakening of metabolism. The deposit of fat in the cells of the intermuscular connective tissue of atrophic muscle may be regarded as due to diminished metabolism in the muscle.

According to *Gautier*, the decomposition of albumin in the cells is the result of their functional activity, and occurs in two phases. In the first, the phase of ferment-



action without oxidation, or hydrolytic splitting, there are formed from the protoplasm urea or analogous combinations (salts of uric acid, kreatin-bodies), and at the same time the carbohydrates form the fat-bodies. In the second, the phase of oxidation, the sugar and fat disappear, both that formed from albumin and that derived from the ingested food. The carbohydrates are in part oxidized; but the greater part, especially during muscular inactivity, are changed into fat through a simple process of fermentation, by which a large amount of carbonic acid is set free. Finally, the fat-bodies are also oxidized and disappear.

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§ 57. **Fatty degeneration** is that form of cell-degeneration in which fat is formed from the albumin of the cell-body—that is, from the albumin of the organism—and appears within the cell in the form of granules, droplets, or drops. **Cells** which are in the condition of fatty degeneration present within their cell-substance



FIG. 62.—Fat-containing liver-cells. a and b, Fat-infiltration; c, d, e, f, fatty degeneration.  $\times 400$ .



FIG. 63.—Fatty degeneration of the heart-muscle.  $\times 350$ .

small or larger droplets, which are clear, and highly refractive (Fig. 62, a, d, e, f, and Fig. 63), insoluble in acetic acid, and soluble in alcohol and ether. With osmic acid they become black (Fig. 64, b and Fig. 65, A, B, C); in

that the fat reduces the osmium tetroxide to a black osmium hydrate. This reaction is obtained only with olein and oleic acid, but not with palmitin and stearin. The number and size of the fat-droplets vary greatly, though the largest rarely attain great size. Thus heart-muscle in a state of fatty degeneration (Fig. 63, Fig. 64, *b* and Fig. 66, *b*) shows, according to the degree of degeneration, a varying number of fat-droplets which are all small and only rarely become confluent, and never form large drops.

A similar appearance is presented in fatty degeneration of liver-cells (Fig. 62, *c*, *d*) and of kidney epithelium (Fig. 65, *A*, *B*), only the size of the fat-droplets is often not so uniform. When the process is far advanced in these organs the degenerated cells containing fat-droplets become loosened from their connection with the neighboring cells and broken up into a *fatty detritus* consisting of fine granules and droplets (Fig. 62, *f*).

Fatty degeneration may occur in connective-tissue cells and muscle as well as in epithelium (Fig. 65, *B*, *C*, *d*). When the entire cell-complex is affected, the condition of



FIG. 64.—Marked fatty degeneration (chronic) of the heart-muscle. (Flemming's solution, safranin.) *a*, Normal muscle; *b*, muscle which has undergone fatty degeneration.  $\times 80$ .



FIG. 65.—Fatty degeneration of the renal epithelium, capillary endothelium, and leucocytes, in diphtheria. (Flemming's solution, safranin.) *A*, Urinary tubules with epithelium (*a*) in a state of fatty degeneration, and containing a hyaline cast (*b*) cut transversely; *B*, intertubular capillary with endothelium showing fatty degeneration; *C*, edge of a glomerulus with epithelium (*c*) showing fatty degeneration, and capillaries (*d*) containing fatty cells; *e*, Bowman's capsule.  $\times 300$ .

fatty degeneration is usually readily recognizable by the naked eye; the more readily of course, the more marked the degeneration, the less striking the natural color of the tissue involved, and the smaller its blood-content. Colorless, transparent tissues, such as the intima of the heart and of the blood-vessels, take on an *opaque whitish* appearance; the cortical tissues of the kidney become *grayish-white*, and in severe cases *opaque yellowish-white*; the heart-muscle becomes *yellowish*, sometimes spotted as the result of localized areas of degeneration (Fig. 64); and the voluntary muscles appear *pale yellowish-brown*.

The cells contained in fluids (pus) or in coagulated masses of exudate very frequently undergo a



fatty degeneration, which leads ultimately to the disintegration of the cells.

The **causes of fatty degeneration** are to be found in a *disturbance of nutrition due to changes in the blood-supply* and in the *composition of the blood*, and in a *lowering of the vitality of the cells*. A chief rôle is played by a *persistent diminution of oxygen*, as a result of which there occurs an increased destruction of albumin with the formation of fat, the nitrogenous end-products in the urine being at the same time increased. Fatty degeneration is observed, therefore, particularly in acute anæmia due to hæmorrhage (heart, optic nerve), in chronic anæmia and leukaemia (heart, liver, intima of the blood-vessels), narrowing and closure of the arteries (in the area supplied by the affected vessel), chronic venous congestion, poisoning with phosphorus, arsenic, chloroform,



FIG. 66.—Fatty degeneration, vacuolization, and disorganization of the heart-muscle in a patient dying from pneumonia and nephritis. (Flemming's safranin.) *a*, Transverse section of normal muscle-cell; *b*, muscle-cell in a state of fatty degeneration; muscle-cells with vacuoles; *d*, disorganized cell.  $\times 400$ .

and many forms of mushrooms (heart, liver, kidneys, blood-vessels, particularly the capillaries), in many infectious diseases, as diphtheria (kidneys, heart, and leucocytes), pneumonia (kidneys, heart) (Fig. 66, *b*), chronic ulcerative pulmonary tuberculosis (kidneys).

In the infectious diseases the fatty degeneration occurring in the glandular organs, the leucocytes and the heart, may be attributed primarily to the effect of the poisons of these diseases; but an increased body temperature, if prolonged, may also produce fatty degeneration of the organs.

Cells which have become loosened from their natural position, and are exposed to new conditions of nutrition—as, for example, leucocytes which have escaped from the vessels in the course of an inflammation, desquamated epithelial cells and loosened connective-tissue cells—also very frequently undergo fatty degeneration. Further, in regenerative and inflammatory proliferations and in tumors, especially in carcinoma, a large part of the cells may die after passing through the stage of fatty

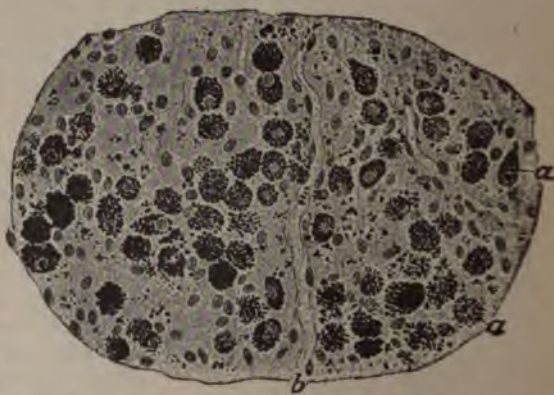


FIG. 67.—Fat-granule cells in an anemic area of softening in the brain. (Marchi's fluid.) *a*, Fat-granule cells; *b*, blood-vessels.  $\times 280$ .

degeneration, for the reason that in these cell-masses there is an insufficient supply of nutrition.

In the majority of cases fatty degeneration is the only histological change which can be demonstrated in the cells, but it is at times associated with other degenerative changes. *The most frequent combination is that of cloudy swelling and granular disintegration with fatty degeneration; but hydropic degeneration with vacuole formation (Fig. 66, c) may also occur at the same time with fatty degeneration.* Both of these combinations occur especially in cases of poisoning and in inflammations. Moreover, fatty degeneration of the cells accompanies many degenerations of the ground-substance, as, for example, amyloid degeneration of the connective tissue (see § 63, Fig. 81).

The question whether the fat found in the cells is a degeneration or a deposit is in many cases very difficult and uncertain of answer; and it often cannot be determined in a given case whether there is a true *fatty degeneration* present, in the sense that the fat is formed in the cell out of the cell-albumin. In general, fatty degeneration is assumed to be present when fat is found in cells which ordinarily contain no fat, and when clinically there is apparent a diminution of functional activity, and anatomically a degeneration of cell-structure. It must be noted, however, that careful investigations (*Unna, Sata*) have shown, that many cells even under normal conditions contain fat more frequently and regularly than has been generally supposed (for example, the epithelium of the sweat-glands and lachrymal gland, and of the epidermis, and also cartilage cells). Moreover, both in fetal tissues and in proliferating cells (not degenerating) with cell-division figures, fat is often present. Under conditions, in which the assumption of a weakening and degeneration of the organ concerned is well founded, nothing further may be recognized by which it is possible to say whether the fat present has arisen from the albumin of the affected cells, or whether it has been produced from carbohydrates or from the lecithin of the cells, or out of substances brought to the cells from without. For this reason we should not go so far as to deny the occurrence of a true fatty degeneration, that is, a formation of fat out of the cell-substance (*Rosenfeld*); but in the diagnosis of cells showing fatty degeneration we must at times bear in mind the different possibilities of the origin of the fat.

Requiring a special consideration are certain round cells of different size, which are entirely filled with fat droplets, and are therefore known as **fat-granule globules** or **fat-granule cells** (Fig. 67, a). They occur especially in degenerative processes in the brain and spinal cord; and have been repeatedly regarded as tissue-cells which have undergone fatty degeneration, in the brain as ganglion-cells and glia-cells presenting this degeneration. The true fat-granule globules or cells are, however, not the fixed tissue-cells which have become fatty, but are *amœboid leucocytes* and *tissue-cells arising through proliferation, which through phagocytic action have taken up into their substance the fatty detritus arising from the disintegration of tissue.* According to *Arnold*, the fat-granules also arise through the conversion of plasmosomes into fat.

According to the investigations of *Lindemann*, the fat arising through degeneration of the heart-muscle differs essentially from the fat deposited in the heart or in the subcutaneous tissue. The degeneration-fat is able to take up 108.55 per cent of iodine, normal heart-fat only 61.1 per cent, the content in free fatty acid amounting to 18.35 as against 7.3 in normal heart-fat.

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§ 58. The **fats** which occur in the human body consist almost entirely of a mixture of the glycerin-esters of oleic, palmitic, and stearic acids which are designated *olein*, *palmitin*, and *stearin*. The first is fluid at ordinary temperatures, the second melts at 46°, the third at 53° C. Since the body-fats contain varying proportions of olein, palmitin, and stearin, they vary in consistency and melting-point. As fat is not soluble in water or watery fluids, the fat in the body, either free or enclosed within cells, is not dissolved in the tissue-fluids. At most, only traces of it are dissolved in the blood, lymph, chyle, and bile, which contain small amounts of soaps. If after death the fat-containing tissues of the body are cooled below the melting-point of the contained fat, the stearin and palmitin may separate and form fine stellate or feathery needles (Fig. 68, *b*, *c*, *d*), which are commonly called **margarin needles**, and which, according to the conditions, are found sometimes in fat-cells, at other times free in the tissue-fluids.

**Cholesterin** occurs in the form of delicate rhombic plates (Fig. 68, *a*), the edges and corners of which are often notched. These may be found wherever there are formed masses of detritus containing fat, arising from degenerating cells or extravasations of blood, as in the diseased tunica vaginalis of the testis, in a dilated sebaceous duct or gland, or in a softened area of degeneration in the wall of a diseased aorta. When the substance in which the cholesterin plates are formed is fluid, these may often be visible to the naked eye as little glistening scales.

Cholesterin is a constant constituent of the bile, and is furnished by the mucous membrane of the gall-bladder and bile-ducts, and held in solution by the bile salts and soaps. It is found also in the medulla of

the nerve-fibres, and in small amounts in the blood, where it is held in solution by fats and soaps. According to Burchard traces of cholesterin are found in all the organs.

Cholesterin is insoluble in water, dilute acids, caustic alkalies, and cold alcohol; it is soluble in boiling alcohol, ether, chloroform, and benzol.

When treated with a mixture of five parts of concentrated sulphuric acid and one part of water the edges of cholesterin crystals take on a carmine-red color, which gradually passes into violet. Sulphuric acid

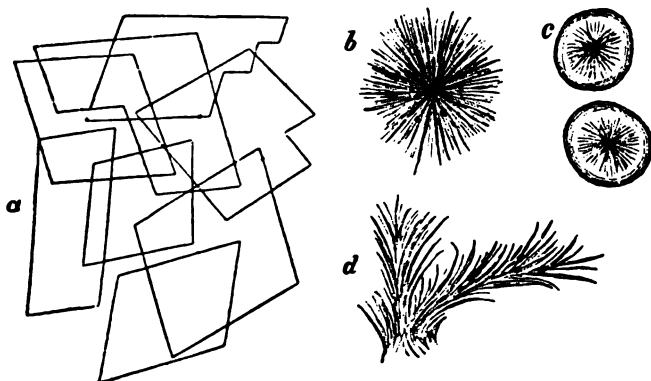


FIG. 68.—a, Cholesterin plates; b, free cluster of margarin needles; c, needles enclosed within fat-cells; d, grass-like bunch of margarin needles.  $\times 300$ .

and water mixed in the proportions of three to one give a violet color to the edges of the crystals. Concentrated sulphuric acid containing a trace of iodine colors the crystals violet, blue, green, and red.

The origin of cholesterin is not known with certainty. It is probable that it is an intermediate product in the decomposition of albumin. Corresponding to this view, it is found under those pathological conditions in which albuminous substances break down with the formation of fat.

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## VII. The Deposit of Glycogen.

§ 59. **Glycogen** is a carbohydrate which is readily convertible into sugar; and in the body is formed chiefly from the carbohydrates of the food, but may also be formed from albumin and gelatin.

In the tissues of the body glycogen is found as a *hyaline substance*, most often within the cells, but occasionally in the tissue-spaces. It usually occurs in the form of spherules of different sizes. In the cells these spherules are most frequently found in the neighborhood of the nucleus.

Glycogen is soluble in water, but the solubility of that found in different tissues varies (Langhans); that found in the liver, kidneys, mus-

cles, and pus-corpuscles is more easily soluble than that of cartilage cells and surface epithelium. Fixation of the tissue in alcohol renders the glycogen less soluble in water. After death the glycogen of the liver is quickly converted into sugar through the action of a diastatic ferment.

*Glycogen becomes brownish-red when treated with iodine.* In order to avoid the solution in water of the glycogen contained in fresh preparations, a syrupy mixture of gum and iodine (Ehrlich), or glycerin to which iodine has been added (Barfurth) may be used when it is desired to test for this reaction. Sections of tissues fixed in alcohol give best results (Langhans) when treated with dilute tincture of iodine (one part tincture of iodine, four parts absolute alcohol), and cleared with oil of origanum, in which the reaction remains preserved for a long time.

Glycogen is present in almost all the tissues of the embryo, also in the foetal membranes at an early period of development; and in the adult body in the liver-cells, muscles, heart-muscle, cartilage cells, epithelium of the body of the uterus, portio vaginalis and vagina (Langhans), in the leucocytes, and in the blood-serum (Gabritschewski). During starvation the glycogen of the liver is diminished, and under pathological conditions may wholly disappear.

In diabetes the epithelial cells of the kidneys show a very rich deposit of glycogen, particularly those of the loops of Henle. In the isthmus of the latter the cells are almost wholly filled with glycogen. If this be dissolved out with water, the cells appear as clear vacuoles. In the blood of diabetic individuals the glycogen, both the intracellular and extracellular, is increased.

In fresh inflammatory exudates glycogen is present in the pus-corpuscles. According to the investigations by Brault all tumors, carcinomata and sarcomata, exhibiting rapid growth contain large amounts of glycogen in their cells, so that these contain large vacuoles. In slowly-growing tumors or in those whose growth is at a standstill, or in those showing beginning degeneration (fatty), glycogen is not present. The tumor-cells form the glycogen, and its presence is not to be regarded as an evidence of degeneration, but rather as a sign of good nutrition and luxuriant cell-growth.

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### VIII. Mucous Degeneration.

§ 60. **Mucous degeneration** has its physiological prototype in the production of mucus by the mucous membranes and mucous glands, and in the formation of mucus in the connective tissue of the umbilical cord, tendons, bursæ, and synovial membranes. In the umbilical cord the mucus occurs as a jelly-like matrix; in the joints, bursæ, and tendon-sheaths it forms a clear, stringy fluid.

In the epithelium of the mucous membranes the mucus appears first in the goblet-cells (Fig. 69, *a*), forming a clear substance which stains with hæmatoxylin. In mucous glands, during the process of mucus formation, the epithelial cells swell, their central portions become clear, and the granules of the protoplasm are reduced to small groups or strands. The so-called mucous corpuscles of the salivary secretion, which are characterized by glassy, transparent contents and vibrating protoplasmic granules, are round cells which have undergone mucous degeneration.

The mucus formed from the protoplasm of the cells may be discharged, and the cells remain intact, or in other cases they may be destroyed.

Mucus is produced in the same way under pathological conditions as under normal (Fig. 69, *a*). In catarrh of the mucous membranes there is an increased formation of mucus by the cells of the superficial epithelium as well as those of the glands. In addition the pus-corpuscles may also undergo mucous degeneration, the mucin being formed from the nuclein of the nuclei (Kossel). In mucous membranes covered with cylindrical cells the number of goblet-cells is increased, and in the secretion there are found cells which have undergone complete mucous degeneration—that is, they have been converted into glassy masses containing few granules. Other cells contain the mucus in the form of drops of varying size.

The epithelium of pathological tissues may also undergo a mucous degeneration, in a manner similar to that occurring in normal tissues. Thus the epithelial lining of cysts of the ovary and of intestinal tumors may often contain numerous goblet-cells (Fig. 70, *a*), and cells which have undergone total mucous degeneration (*b*). In the so-called gelatinous or mucoid carcinoma (colloid carcinoma) a large part of the epithelial cells suffer a mucous metamorphosis.

Of the connective tissues, which may suffer a mucous degeneration and



FIG. 69.—Formation of mucus within the epithelial cells of an adenomatous polyp of the small intestine. (Alcohol, hæmatoxylin.) *a*, Epithelium with dark-stained (hæmatoxylin) drops of mucus within the cells; *b*, free mucus; *c*, leucocytes in the epithelium.  $\times 300$ .



thereby acquire a gelatinous, transparent appearance, may be mentioned fibrous connective tissue, also cartilage, bone, adipose tissue, bone-marrow, and sarcomatous tissue. In these tissues it is chiefly the ground-substance (Fig. 71, *b*) which undergoes mucous change and is converted into a homogeneous, structureless mass. The cells may remain unchanged, or may become fatty, or also undergo mucous degeneration. In the last event the entire tissue ultimately forms a hyaline mass, in



FIG. 70.

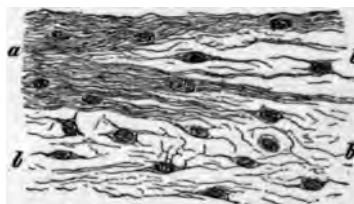


FIG. 71.

FIG. 70.—Epithelial cells which have undergone mucous degeneration, from a cystadenoma of the ovary. *a*, Cells showing slight change; *b*, cells showing marked degree of mucous change.  $\times 400$ .

FIG. 71.—Mucous degeneration of the connective tissue of the aortic valves (osmic acid, glycerin). *a*, Fibrous tissue; *b*, myxomatous tissue.  $\times 350$ .

which only scattered fibres of connective tissue, or single cells or groups of cells are left to suggest the original tissue.

The stringy, or gelatinous material, which results from mucous degeneration, does not represent a single chemical substance; in it there may be found different varieties of mucins as well as of pseudomucins.

The **mucins** (submaxillary, intestinal, and tendon mucin) are nitrogenous substances somewhat resembling albumin. They dissolve or swell up in water forming a stringy, mucous fluid, from which they may be precipitated in a stringy form by means of alcohol or acetic acid; but differ from the true albumins in the fact that the precipitate is not redissolved in an excess of the acid. The precipitated mucins are soluble in neutral salt-solutions, caustic alkalis, and alkaline carbonates; and are gradually converted into alkali-albuminates in case of solution by the last named.

All mucins contain nitrogen and sulphur; their content in carbon, oxygen, nitrogen, and sulphur varies in the different forms. By proper treatment a carbohydrate, called animal gum (Landwehr, Hammarsten), may be split off from the mucins. For this reason mucin may be called a glycoproteid (Pfannenstiel).

**Pseudomucin** also dissolves in water, forming a gelatinous fluid, from which it may be precipitated in stringy masses by alcohol. The precipitate redissolves in water. Solutions of pseudomucin are not precipitated by acetic acid. Boiling with dilute mineral acids leads to the splitting-off of a carbohydrate (as is the case with mucin), which reduces copper sulphate in alkaline solution (Pfannenstiel).

Pseudomucin is found particularly in ovarian cystomata, and is the cause of the gelatinous character of the cyst-contents. It is produced by the epithelium of these tumors (Fig. 70); and in its formation the same changes take place in the cells, as in the formation of mucin from epithelium. In all probability the mucous substance present in gelatinous carcinomata is a body closely related to pseudomucin or metalbumin—that is, there are different varieties of pseudomucin (Pfannenstiel), of which the two mentioned are examples.

The mucin-like substances, precipitable by acetic acid, which occur in the *synovial fluid*, differ, according to *Salkowski*, from nuclealbumin in the absence of phosphorus. From ordinary mucin they are distinguished by their different behavior with mineral acids; when boiled with dilute hydrochloric acid no reducing substance is obtained.

*Mitjukoff* has obtained from the gelatinous contents of an ovarian cyst a mucin-like substance which he has named *paramucin*. It differs from pseudomucin chiefly in the fact that without previous boiling with dilute acids it reduces copper oxide in an alkaline solution.

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### IX. Formation of Epithelial Colloid and Epithelial Hyaline Concretions.

§ 61. The **epithelial formation of colloid** is a process closely related to the epithelial production of mucus; it consists partly in a secretion of

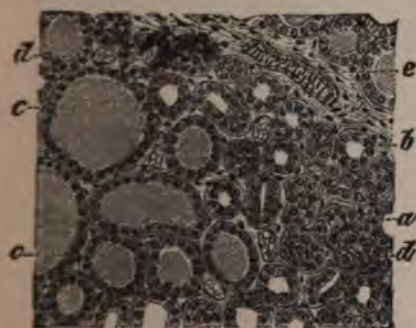


FIG. 72.

FIG. 72.—Colloid in enlarged thyroid gland. (Alcohol, hæmatoxylin.) *a*, Follicle filled with cells; *b*, follicle showing lumen; *c*, masses of colloid; *d*, capillary; *e*, connective-tissue septum with artery.  $\times 60$ .



FIG. 73.

FIG. 73.—Secretion of colloid in the thyroid. (After Bozzi.) *a*, Colloid; *b*, secreting cells with granules.

colloid by gland-cells, and partly in a conversion of entire cells into colloid. Physiologically, colloid is found in the thyroid (Fig. 72), where it



appears in the form of *hyaline, rather firm, colorless, or slightly colored, jelly-like masses*, which in the first place fill the follicles (c), but from these may extend into the lymph-vessels of the thyroid. *Pathological*

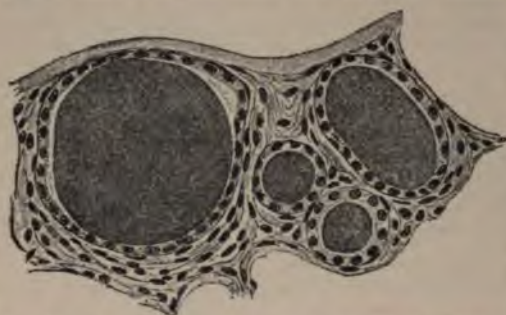


FIG. 74.—Dilated urinary tubules filled with colloid. (Müller's fluid, hematoxylin, and eosin.)  $\times 250$ .

*collections of colloid* occur both in normal gland-tissue and in newly-formed glandular-tissue of pathological nature. The accumulation causes a more or less marked distention of the follicles, and thereby leads to an enlargement of the affected gland, which is known as colloid goitre or bronchocele.

The typical secretion of colloid is characterized by the formation of homogeneous granules and spherules

in that portion of the epithelial cells next to the lumen of the follicle (Fig. 73). Some of the cells may be completely filled with these granules. In excessive and atypical formation desquamated cells may become converted into the hyaline substance of colloid.

The colloid of the thyroid is found on microscopical examination to be *homogeneous*; and according to its appearance it may be designated **epithelial hyalin**. As a rule it incloses no cellular elements, but degenerating cells may be found in it. Alcohol and acetic acid cause no clouding, or precipitation in the form of threads, as happens in the case of mucin when so treated. By means of Van Gieson's staining method the colloid is stained orange-red, while the connective tissue takes a fuchsin-red. It must be noted that the contents of the thyroid follicles, which are designated colloid, are not always of the same character. At one time the substance is firm, at another soft or even fluid, or at least is readily soluble in water. In prepara-



FIG. 75.—Colloid concretions in the cystic dilated tubules of the parovarium. (Formalin, Van Gieson's stain.) a, b, Gland-tubules of the parovarium; c, cysts containing colloid concretions (d).  $\times 80$ .

tions fixed in alcohol a granulation or cleavage may be caused by contraction; and the staining reactions are not always the same.

The chemical nature of the thyroid colloid is not fully known, and it is probable that the contents of the follicles are of variable composition. It is most probably an albuminoid body which is combined with iodothy-



Epithelial hyalin is also found in the glands of the hypophysis cerebri, in the urinary tubules of diseased kidneys (Fig. 74), in the prostate (Fig. 76, *d*), in cysts of the parovarium (Fig. 75, *d*), in the glands of the stomach, and more rarely in other glands. In the last-named organs the hyalin occurs in the form of a uniformly homogeneous mass completely



FIG. 76.—Section from a hypertrophic prostate with concretions. (Müller's fluid, hæmatoxylin, and eosin.) *a*, Stroma; *b*, glands; *c*, dilated glands; *d*, concretions.  $\times 45$ .

filling the gland-lumen, or often as **hyaline**, in part **laminated concretions** (Fig. 75, *d*, and Fig. 76, *d*) of more or less firm consistency.

It must not be assumed that the last-named formations are identical in their chemical composition with thyroid colloid. The only thing which they possess in common is this: they both represent *transformed protoplasm of gland-cells*—a substance which is *hyaline*, possesses a certain firmness, and *does not react to chemical reagents in the same manner as does mucin*. These concretions may also undergo changes which necessitate, on their part, a different behavior toward microchemical reactions. This is particularly true of the prostatic concretions, which not infrequently show, when treated with iodine, a reaction that has been taken as evidence that they are composed of amyloid material (see § 64). It may be proved, both in the case of prostatic concretions and of renal colloid, that they represent cell-material which has become changed into hyaline substance. In the case of renal colloid, however, it is only under especial conditions that the participation in its formation of albumin derived from the glomeruli may be excluded.

**Colloid** is a **collective term** which is applied to a great variety of formations that possess only certain physical attributes in common. There is a very great difference of opinion among authors as to the application of the term. Under colloid degeneration, for example, *von Recklinghausen* places mucous, amyloid, and hyaline degenerations; including under the last-named epithelial colloid-formation, hyaline degeneration of connective tissue, as well as hyaline coagulation-necroses and hyaline thrombi. *Marchand* gives the term a more limited application, but includes under colloid certain forms of epithelial mucin-formation (particularly in tumors), and also hyaline formations in connective tissue. Inasmuch as colloid is not a definite chemical entity, and as its staining-reactions do not differentiate it sharply from other hyaline substances, it seems to me most expedient to apply the term only to those hyaline products of epithe-

Hum which do not possess the characteristics of mucin. I have, therefore, also classified as colloid those epithelial concretions which on account of their reaction with iodine (brown or blue color when treated with dilute iodine solutions) have hitherto been regarded as amyloid bodies. If objection is made to the classification of these formations as colloid, they may be placed under the heading of **epithelial hyalin**.

As epithelial hyalin (keratohyalin?) may be classed also the *hyaline granules and spherules* described by *Russel, Klein*, and others, and which are found especially in cancer cells. They stain intensely with fuchsin, and also with Gram's method or with Weigert's fibrin stain. It should be noted further that similar bodies of varying size and form have been observed in the epithelium during the development of a vaccination pustule (*Hücker*), and have been by many regarded as parasites.

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### X. The Pathological Cornification of Epithelium.

§ 62. The **cornification of the surface epithelium** over the entire skin is a physiological process, characterized essentially by the fact that the cells in the outer strata of the prickle layer of the *stratum germinativum* undergo a horny change. This cornification takes place first at the periphery of the cells and in the processes binding the cells together, while at the same time the inner portions of the cell and the nucleus shrink, so that the cells become changed into thin, flat, horny scales. This horny substance or *keratin* is a very resistant modified albuminoid body of homogeneous composition, and is capable of resisting digestion by the gastric or pancreatic juices.

As accompanying phenomena of cornification there appear in the cells of the prickle layer peculiar hyaline granules and spherules resembling colloid, which stain intensely with nuclear stains and are known as *keratohyalin* (Waldayer). In those areas of the skin possessing a thick horny layer, there is formed a sharply limited layer of such keratohyalin-containing cells; this layer is known as the *stratum granulosum*. In those places where the horny layer is thin, the stratum granulosum is imperfectly developed and exhibits breaks of continuity.

**Pathological cornification** may occur, in the first place, as a widespread or localized increase of the horny layer, resulting in a condition of *hypertrophy of the horny layer of the epidermis* (see Chapter VI., § 77),

or *hyperkeratosis*. This phenomenon may be primary—that is, due to intrinsic causes inherent in the anlage of the skin (ichthyosis, lichen pilaris)—or may be acquired as the result of external influences, mechanical lesions, infections and inflammations (callosities, corns). Further, there may occur disturbances in the process of cornification of the skin, so that certain pathological manifestations recognizable by the naked eye may make their appearance, such as desquamation of the skin. Such changes are included under the term *parakeratoses*. They occur especially as sequelæ or concomitant phenomena of infections of the epidermis, and of inflammations of the corium and papillary body, sometimes without any recognizable cause; and in these cases either the process of cornification or of the formation of keratohyalin, or both, is disturbed.

Finally, *pathological cornification often occurs in regions where normally it either does not occur at all or but to a slight extent*. In the skin the cornification may extend to the ducts of the sebaceous glands and to the hair-follicles (ichthyosis) or to the sweat-glands (porokeratosis). Further, pathological cornification occurs not infrequently in the mucous membrane of the mouth, giving rise to white thickenings of the epithelium or to hair-like formations (hairy tongue). Horny change may be observed also in the mucous membrane of the middle ear, in the mastoid cells, in the descending urinary passages (*formation of cholesteatomata*), and in these places it may lead to the formation of shining white scales.

*Cornification of cancer cells* is not infrequently seen, particularly in cancers of the skin, in which the horny scales are found usually in the form of round masses resembling onions or pearls. Similar horny products are also found in *cholesteatomata of the pia and brain*.

The pathological formation of horny substance in the mucous membranes or in tumors takes place either simply through cornification of the cell-membranes with contraction of the cell, or it may be combined with the formation of keratohyalin as in the case of typical cornification. The formation of keratohyalin and the cornification of epithelial cells often occur irregularly distributed, particularly in cancers.

According to the view of *Mertsching* and *Ernst*, the granules of keratohyalin are derived from the nucleus, and represent chromatin which has escaped from the nucleus. In favor of this view is the fact that the nuclei lose their chromatin simultaneously with the appearance of the keratohyalin.

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### XI. Amyloid Degeneration and the Amyloid Concretions.

§ 63. **Amyloid degeneration is a peculiar degeneration of the connective tissue of the blood-vessels**, characterized by a *deposit of an albuminoid substance (amyloid)* in the affected part, so that the tissue increases in mass and at the same time acquires a peculiar, *glassy, homogeneous appearance*. The degeneration may occur in almost all the organs of the body; but is especially frequent in the spleen, liver, kidneys, intestine, stomach, adrenals, pancreas, and the lymph-glands. It is more rarely observed in adipose tissue, thyroid gland, aorta, heart, muscles, ovaries, uterus, and in the urinary passages.

Extensive deposits of amyloid may be recognized by the naked eye, as the affected parts present a translucent appearance resembling bacon (*lardaceous degeneration*).

In the *spleen* the change occurs most frequently in the follicles, which in a certain stage of the degeneration may become converted into homogeneous, translucent bodies (Fig. 77, *b*) resembling grains of boiled sago, wherefore this form of amyloid spleen is known as *sago spleen*. When the amyloid change occurs throughout the spleen-pulp it may be recognized on the cut surface of the organ as more or less distinct spots or streaks. Ultimately the greater part of the substance of the spleen may become affected. The spleen is thus enlarged, its consistency becomes

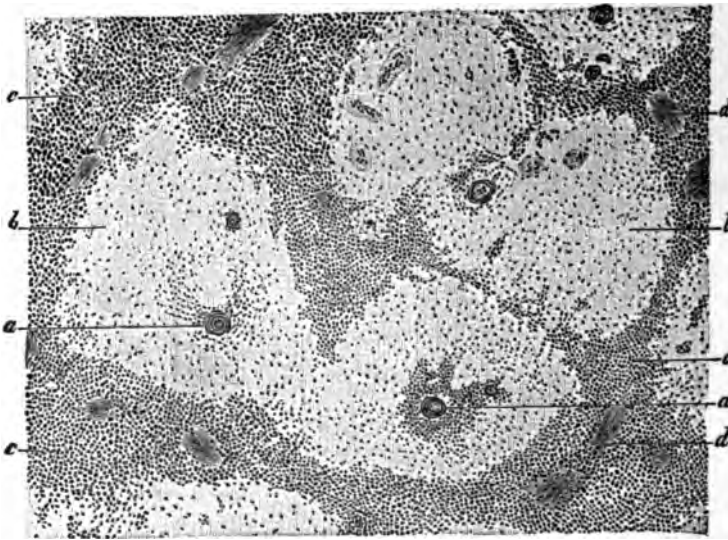


FIG. 77.—Amyloid degeneration of the splenic follicles and neighboring tissue. (Müller's fluid, haematoxylin, and eosin.) *a*, Transverse section of splenic artery; *b*, amyloid areas; *c*, pulp; *d*, trabeculae.  $\times 30$ .

very hard, and the organ under certain conditions may be completely transformed into a bacon-like substance (*lardaceous spleen*).

The *liver*, in cases of well-marked amyloid degeneration, is increased in size and of a firmer consistency. On section, the liver-tissue is found to be replaced to a greater or less extent by translucent, lardaceous masses, between which the remains of the liver-tissue appear as brownish or yellowish (from abundance of contained fat) areas.



The *kidney*, in cases of extensive amyloid change, is likewise enlarged and hardened, and on section shows hyaline, lardaceous spots and streaks of firm consistency. More frequently there is found a white, fatty, swollen, or normal-sized kidney, in which only here and there may be seen small hyaline granules or streaks, or the presence of amyloid may be recognized only after the tissues have been treated with iodine.

In the intestine and lymph-glands the degeneration usually cannot be recognized without the aid of the microscope and chemical reagents; and the same thing is true in regard to the other organs which are more rarely affected, such as adipose tissue, heart-muscle, the great blood-vessels, the thyroid gland, etc.

The substance which is deposited in amyloid degeneration forms chiefly **shining, homogeneous masses**, which exhibit a *characteristic reaction with iodine as well as with various aniline dyes*. Iodine dissolved in water, or better in a solution of

potassium iodide, and poured over the affected tissue, stains the amyloid substance a *dark brownish-red* (mahogany brown). In thin sections, under the microscope, the amyloid appears *bright brown-red* (Fig. 78, *b*) while the remaining tissue is of a straw-yellow color (*a*).

In marked amyloid degeneration, when the tissues are of a wooden hardness, the iodine reaction sometimes gives a *blue or green color*. Preparations which have been changed to a mahogany brown through the action of iodine become still deeper brown when treated with dilute sulphuric acid or with a solution of zinc chloride, or they may become bright red, violet, blue, or green. This reaction is, however, imperfect in the majority of cases.

*Methyl violet* stains amyloid a *ruby red* (Fig. 78, *a, b*), while the normal tissue takes a blue or dark blue-violet.

Because of the peculiar reaction with iodine, Virchow was led to regard the amyloid substance as a non-nitrogenous body closely related to cellulose or starch, inasmuch as cellulose when treated with iodine and concentrated sulphuric acid becomes bright blue, and starch similarly treated gives an ultramarine color. Virchow accordingly gave the name amyloid to the newly discovered substance. Several years later Friedrich and Kekulé showed that amyloid is a nitrogenous body of an albuminous nature. According to the investigations of Krawkow amyloid is a firm combination of chondroitin-sulphuric acid with an albumin.

The peculiar reactions of amyloid enable us to detect its presence in the tissues when it is present in such small amounts as to be otherwise

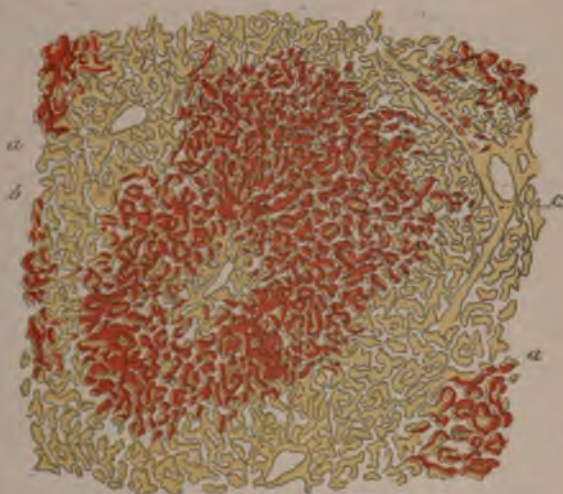


FIG. 78.—Section from amyloid liver treated with iodine. *a*, Normal liver-tissue; *b*, amyloid areas; *c*, Glisson's capsule.  $\times 15$ .



practically invisible. In the microscopic examination of fresh preparations care should be taken to wash out the blood from the piece of tissue, since the color resulting from the combination of the blood and the iodine may be deceptive.

Amyloid is very resistant to acids and alkalies. Alcohol and chromic acid do not affect it; and it is also very resistant to putrefactive changes.

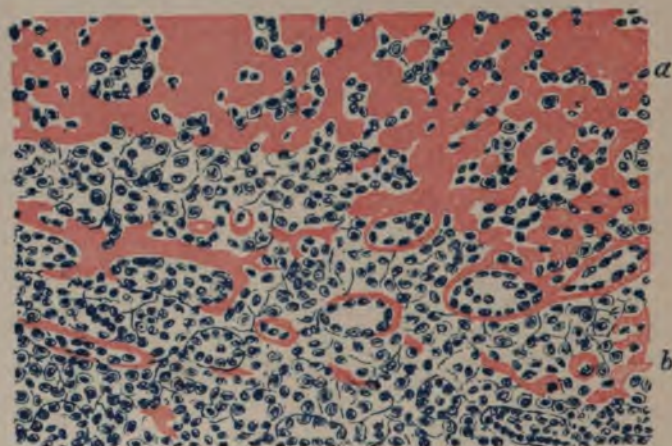


FIG. 79.—Amyloid degeneration of the splenic follicles and pulp. (Alcohol, methyl violet, hydrochloric acid.) *a*, Follicle showing marked degeneration; *b*, pulp showing beginning degeneration.  $\times 300$ .

**Amyloid is deposited** in the ground-substance of the connective tissue of the blood-vessels, especially in the walls of the small vessels. Living cells are not affected. In the connective tissue the amyloid substance appears first between the fibrillæ.

In the acini of the liver the amyloid is found along the capillaries. The endothelium (Fig. 80, *c*) is covered on its outer side by a thick layer of a homogeneous, glassy substance, which in part may be broken up through numerous clefts into lumpy masses (*c*) of amyloid material. The liver-cells between the amyloid masses are either intact (*a*) or compressed (*b*), or already atrophic, or may have wholly disappeared. They very often contain fat. The afferent blood-vessels of the liver, particularly the media of the arteries, may also show amyloid deposits.

In the kidneys (Fig. 81) the amyloid is found particularly in the vessel-walls. The capillaries of the glomeruli (*b*) may be greatly thickened and homogeneous; likewise the arteries (*i*), the veins, and the capillaries (*k*) of other parts of the renal parenchyma may show amyloid deposits. In the intestinal mucosa the deposit is also found particularly in the walls of the blood-vessels.

In fat-tissue, which is occasionally extensively involved, the amyloid substance is found partly in the vessel-walls, and partly in the connective tissue, and the membranous sheath of the fat-cells may be entirely converted into a hyaline mass. In the spleen the connective-tissue trabeculæ (Fig. 79, *a*, *b*) and the vessel-walls are especially likely to be affected, and may suffer a marked thickening (*b*). In striped muscle the perimysium internum and the sarcolemma are involved. In glandular organs possessing a tunica propria, as, for example, the mucous

glands and the kidneys, this membrane may become affected and greatly thickened.

The **results** of amyloid degeneration upon the functions and vitality of the affected organ are shown, through anatomical investigation, most prominently in the marked *change of structure* on the one hand, and on the other hand in the associated *degeneration* and the *disappearance of the cellular elements*. Amyloid disease is eminently degenerative in character. The connective tissue itself is permanently changed, as the practically insoluble amyloid is never removed from it.

The deposit of amyloid substance in the tissues of the blood-vessels leads to a very marked thickening of their walls, and to a narrowing or even obliteration of their lumina (Fig. 81, *b*), and in this way to a permanent disturbance of circulation. The amyloid masses may compress neighboring epithelial structures (Fig. 80) and cause them to atrophy. Often there is associated a fatty degeneration of the epithelium (Fig. 81, *e, f*), particularly in the kidneys; but this change is not to be referred wholly to the disturbances of circulation caused by the amyloid deposit. It is more likely that the fatty degeneration, at least in part, is a pathological process running parallel with the amyloid disease, and caused by the same conditions producing the latter. Consequently, in some cases the amyloid change may be slight, while the fatty degeneration is very marked.

In the spleen and lymph-glands the lymphoid cells lying in the meshes of the thickened reticulum (Fig. 79) disappear as the result of atrophy and fatty degeneration. In muscles the contractile substance



FIG. 80.—Amyloid degeneration of the liver. (Alcohol, Van Gieson's.) *a*, Liver-cells, in part containing fat; *b*, compressed liver-cells; *c*, amyloid.  $\times 240$ .

diminishes in proportion to the increase of the amyloid deposit in connective tissue.

**Amyloid deposit** is usually a sequela of cachexia due to *chronic ulcerative tuberculosis* of different organs, *chronic suppuration* (for example, of the bones), *syphilis*, or *chronic dysentery*. In the cachexia of carcinoma



it is but rarely observed. In rare cases the degeneration occurs without being associated with any of the above-mentioned diseases.

According to investigations by Czerny, Krawkow, Lubarsch, Davidsohn, Maximow, Nowak, Petrone, and Schepilewsky amyloid may be produced experimentally in the spleen, liver, kidneys, and intestines of various animals, rabbits, chickens, doves, mice, and dogs, through the production of suppurations lasting several weeks. Suppurative processes caused by staphylococci and oil of turpentine appear in particular to favor the formation of amyloid. In a number of cases amyloid was also successfully produced through injections of decomposed bouillon, dead cultures of staphylococci, rennet-ferment, and pancreatin (Schepilewsky), when the inflammation produced by these agencies ran a somewhat

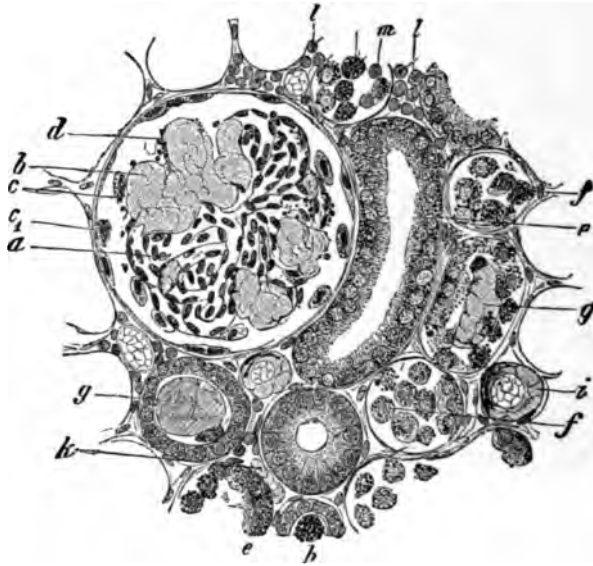


FIG. 81.—Section of an amyloid kidney. (Müller's fluid, osmic acid, methyl violet.) *a*, Normal vascular loops; *b*, amyloid vascular loops; *c*, fatty glomerular epithelium; *c*<sub>1</sub>, fatty capsular epithelium; *d*, fat-drops lying against the outer surface of the capillary walls; *e*, fatty epithelium *in situ*; *f*, desquamated and fatty epithelium; *g*, hyaline coagula (cast); *h*, transverse section of a cast composed of fat-drops; *i*, amyloid artery; *k*, amyloid capillary; *l*, cellular infiltration of the connective tissue; *m*, round cells within the tubules.  $\times 300$ .

chronic course. Krawkow observed the beginning of amyloid formation after three days, Nowak after eight days.

The origin of the amyloid substance has not yet been definitely determined. The results of experimental investigation vary greatly, the degeneration being often absent in cases of chronic suppuration (particularly in dogs). It is probable that the blood brings to the tissues some substance which is changed into amyloid at the site of deposit. It has been many times shown that as the antecedent of amyloid there is found a hyaline substance in the tissues, which does not give the amyloid reactions. Similar observations have been occasionally made in man. The material from which amyloid arises is formed, perhaps, by disintegrating pus-cells or tissue-cells at the seat of the primary disease.

According to Krawkow, there are found normally in the artery-wall of the horse, in the ligamentum nuchæ of cattle, in the stroma of the spleen of calves, and in the mu-

cous membrane of the stomach, combinations of chondroitin-sulphuric acid which are closely related to amyloid.

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§ 64. The form of amyloid degeneration just considered is a disease, which usually appears as a multiple affection of several organs, or, if confined to a single organ, appears as a diffuse change extending throughout the whole organ. There is, however, a localized form of amyloid deposit, appearing either as a *local amyloid infiltration of the tissues* or in the *form of free concretions*.

The **local amyloid infiltrations** occur in part in very cellular granulations (conjunctiva) and in tissues showing chronic inflammatory processes; and in part in scars and in hyperplastic proliferations of connective tissue. They are also found occasionally in tumors in which other retrograde changes have begun. In certain cases only small deposits are found in the affected tissues, usually in the vessel-walls. In other cases

larger nodules consisting almost wholly of amyloid may be formed, and these may acquire a wooden hardness.

Here also the *amyloid substance is deposited in the ground-substance of the tissue*; but it has been claimed by some authors (Rählmann) that the cells of the tissue may acquire a hyaline appearance and give the amyloid reactions.

Such local formations of amyloid have been found in the inflamed conjunctiva, in syphilitic scars of the liver, tongue, and larynx, in inflamed lymph-glands, ulcers of bone, and in tumors of the larynx and stomach. *Tumor-like nodules of amyloid* also occur in the conjunctiva, tongue, larynx, and trachea under conditions in which it is impossible to establish any relationship between them and inflammatory processes, and where besides the hyaline masses there is but little normal connective tissue present. According to Manasse such tumors may arise also from sarcoma-like proliferations.

**Free amyloid concretions** or **corpora amylacea** occur most frequently in the tissues of the central nervous system, especially in the substance of the spinal cord, and in the ependyma of the ventricle. They are

found also in the prostate. In the nervous system they appear as small (Fig. 82, c), dull-shining, mostly homogeneous bodies, more rarely consisting of a nucleus and an outer shell (Redlich); in the prostate they form larger (Fig. 82, a) bodies which usually show a distinct stratification. Corpora amylacea have also been found in carcinomata (Wagner, Langhans), and have been repeatedly observed in the lung (Friedreich, Zahn, Ziegler), where they occur in inflammatory areas, hæmorrhagic extravasations (b), and in emphysema.

*The local deposits of amyloid and the free amyloid concretions cannot be regarded as being wholly of the same nature as the progressive amyloid degeneration of connective tissue.* Some

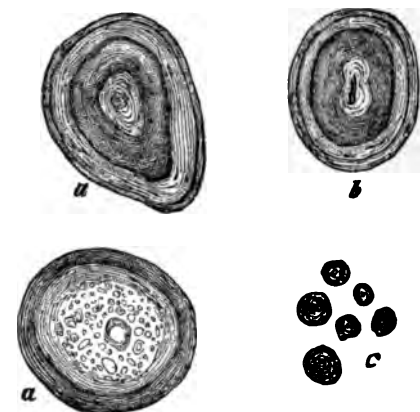


FIG. 82.—Corpora amylacea. a, Laminated prostatic concretions.  $\times 200$ . b, Corpus amylaceum from an old hæmorrhagic infarct of the lung, with hæmatoidin crystals in its nucleus.  $\times 200$ . c, Corpora amylacea from the spinal cord.  $\times 400$ .

of them indeed give characteristic amyloid reactions, and the corpora amylacea of the nervous system, in particular, become blue when treated with iodine and sulphuric acid. But, in the case of these bodies, we have to do with formations which are dependent essentially upon local conditions for their origin; and which are derived in part from epithelium, and in part from connective-tissue cells. They are, therefore, to be regarded partly as modified epithelial hyalin (§ 61), and partly as modified connective-tissue hyalin (§ 66). The prostatic concretions are formed through the fusion of masses of degenerating epithelial cells or of fragments of the same (epithelial colloid, § 61); and the similar bodies found in the lungs and in tumors are composed essentially of the products of disintegrated cells, though in part also of albumin derived from the blood. Redlich considers the corpora amylacea of the nervous system, which stain deeply with hæmatoxylin, to be derived from the nuclei of the neuroglia-cells, and to represent a senile retrograde change of

the tissue. On the other hand, according to Stroebe, they are formed from fragments of swollen axis-cylinders, while by Siegert they are believed to be of cellular origin.

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## XII. Hyaline Degeneration of Connective Tissue and the Hyaline Products of Connective-tissue Cells.

§ 65. Under the head of **hyaline degeneration of connective tissue** may be grouped those changes in which the *fibrous ground-substance of the connective tissue of the blood-vessels acquires a hyaline character without giving the specific reactions of amyloid* (Fig. 83). The change may involve normal connective tissue (Fig. 83), or that altered by inflammation, as well as the newly formed connective tissue of inflammatory new-growths and of tumors. It is dependent partly upon local and partly upon general disturbances of circulation. Hyaline degeneration is found most often in the connective tissue of the thyroid (Fig. 83, b); the valvular endocardium; intima of the arteries; the entire wall of the smaller vessels, particularly of the brain and spinal cord; the lymph-glands (Fig. 85, a, b); glomeruli of the kidney; the connective tissue and blood-vessels of connective tissue tumors of the dura mater (psammoma), parotid, and submaxillary glands (angiosarcoma); the connective tissue of corneal scars; the peripheral portions of tuberculous nodules; the connective tissue of tuberculous tendon-sheaths and bursæ mucosæ (Fig. 84, b).

Hyaline degeneration of connective tissue possesses no specific staining

reactions, as does amyloid. Staining with Van Gieson's (acid fuchsin and picric acid) gives to hyalin in the great majority of cases an intense

fuchsin red; but this reaction is sometimes wanting. It is probable that the degeneration of connective tissue known as hyaline represents a variety of degenerative conditions. By many authors hyaline coagula of exudates, occurring in the tissues, are included in this group.

In many cases (thickening of the heart-valves or of the intima of arteries) the tissue appears on microscopical examination to be very thick and dense, and from this fact the condition has been designated **sclerosis**. The cause of the thickening

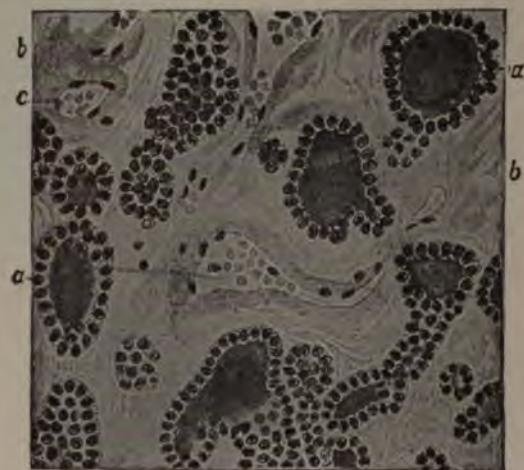


FIG. 83.—Hyaline degeneration of the connective tissue of a colloid goitre. (Alcohol, Van Gieson's.) *a*, Follicles containing colloid; *b*, hyaline connective tissue; *c*, blood-vessel.  $\times 300$ .

and homogenous character is not known. The gradual disappearance of the nuclei, the subsequent calcification (see § 67), or softening even to the point of complete disintegration (for example in sclerotic areas of the intima), the sequestration of the altered tissue from the normal (for example, in the degenerated portions of the walls of the bursæ), all point to the fact that the process is essentially degenerative in character.

In other cases the appearance of the hyaline tissue resembles closely that of amyloid degeneration, and there is associated with the hyaline change a pronounced increase of bulk, particularly so in the case of hyaline degeneration of the small vessels of the central nervous system, glomeruli, and the lymph-glands (Fig. 85, *a*, *b*), more rarely in the hyaline degeneration of the connective tissue itself. There occur, moreover, though very rarely, certain forms of hyaline degeneration involving several organs, the heart (Fig. 86, *b*, *c*), serous membranes, intestinal wall, etc., with the formation of glassy masses, which in part give the amyloid reaction, and in part do not. In proliferations of the conjunctiva there have been frequently observed hyaline degenerations of the reticular ground-substance with nodular thickenings of the same; and these changes give the amyloid reaction only in



FIG. 84.—Hyaline degeneration of the connective tissue of the wall of a tuberculous bursa. (Müller's fluid, hæmatoxylin, and eosin.) *a*, Fibrous connective tissue; *b*, hyaline connective tissue.  $\times 40$ .



part. It may therefore be assumed that there is a form of hyaline degeneration of the connective tissue, which is closely related to amyloid, and may become changed into the latter (see § 63); and that it arises



FIG. 85.

FIG. 85.—Hyaline degeneration of the blood-vessels of an atrophic axillary lymph-gland. (Alcohol, carmine.) *a*, Hyaline vessel with open lumen; *b*, obliterated vessel.  $\times 200$ .

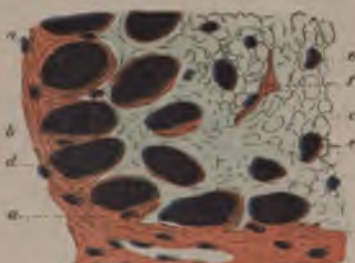


FIG. 86.

FIG. 86.—Hyaline degeneration of the connective tissue of the myocardium. (Alcohol, hematoxylin, carmine.) *a*, Normal connective tissue; *b*, hyaline connective tissue; *c*, hyaline masses; *d*, transverse section of normal muscle-cells, of atrophic (*c*).  $\times 250$ .

through the deposit of a hyaline insoluble albuminous body which is probably derived from the blood.

The preparation shown in Fig. 86 was taken from the heart of a woman of fifty-five years of age, the greater part of the heart-wall presenting a hyaline degeneration. In both endo- and pericardium there were numerous hyaline nodules and flattened masses. The muscle tissue was in part degenerated, as shown in the figure. Associated with this condition there was extensive degeneration of the blood-vessels, particularly of the intestines, tongue, lungs, heart, and urinary bladder. The peritoneum was also thickly covered with hyaline nodules. The fact that the small areas and the periphery of the larger ones gave no iodine-reaction, while the central portions of the larger areas did so, appears to point conclusively to a close relationship between hyaline degeneration and amyloid. This is further supported by the fact that amyloid organs occasionally contain areas of hyaline degeneration which give no iodine reaction.

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§ 66. **Hyaline products of connective-tissue cells** arise in the first place from spherical masses of *flat connective-tissue cells arranged in concentric layers*, which, in a manner similar to the cornification of epithelial cells, become changed into a *hyaline substance containing no nuclei*. These formations occur most frequently in the meninges, the choroid plexus, and the pineal gland, and in the new-growths arising in these regions. Through subsequent calcification they lead to the formation of laminated concretions of calcium salts (see § 67, Fig. 92).

Another kind of hyaline formation probably owes its origin to a secretory activity of the connective-tissue cells. This may be designated *secretory connective-tissue hyalin*, but it must be noted that under this term there is included a variety of different formations, and that, as in the production of colloid, the *cells as a whole may be converted into hyaline products*. In this category may be placed first the so-called *granules* (granula)—that is, the small granules which are found in the protoplasm of certain leucocytes, and also in many connective-tissue cells in both normal and inflamed, or otherwise altered, or proliferating tissues. Some of these granules are oxyphile, and stain especially with eosin, so that they have been designated *eosinophile cells*. Others stain intensely with basic stains, and are usually designated as *mast-cells* (Ehrlich). In both forms of cells the granules may be so numerous as to convert the cells into granule-spheres.

Further belong here certain granules and spherules of hyaline appearance which stain especially intensely with fuchsin, though staining also with methyl violet, gentian violet, etc.; and which are known as *fuchsinophile bodies*. They are also often called Russel's bodies from the fact that they were described closely by Russel, who regarded them as parasitic fission-fungi. In the sand-tumors of the meninges the antecedents of the calcareous granules may be represented by intracellular hyaline spherules.

Fuchsinophile bodies are found both in normal and in slightly altered tissues (adrenals, various mucous membranes—as that of the stomach—in the brain, spleen, and lymphadenoid tissues), also in inflamed tissues (particularly the mucous membranes, for example, of the stomach), inflammatory new-growths (polypi of the stomach), and in connective-tissue tumors. They are partly intracellular, sometimes in great numbers, and partly extracellular. They are to be regarded as cell-products, probably of the nature of a cell-secretion, or formed as the result of the disintegration of the cells. Of their genesis and their composition nothing definitely is known; it is possible that they have a close relationship with the mast-cells. Those occurring in the brain and spinal cord are generally classed with the corpora amylacea (§ 64), even when they give no specific iodine reaction.

Finally, there should be considered in this connection the larger *hyaline spherules and casts of tubes* (changed blood-vessels) resembling epithelial colloid, which are not infrequently seen in sarcomata (see Endothelioma and Angiosarcoma), inasmuch as these formations are also to be regarded as products either of a secretory or of a degenerative process on the part of cells.

The *significance of the granules* of eosinophile and mast-cells, as well as the neutrophile granules of the leucocytes (which stain with a neutral dye obtained through a mixture of acid fuchsin and basic methyl green), cannot be positively stated at the present time. *Ehrlich*, *Heidenhain*, and *Löwit* regard the granules of the leucocytes as secretory products of a specific metabolism of the cells in which they are found, so that these cells may be looked upon as unicellular glands. By some writers (*Browicz*, *Roudnitz*) the so-called mast-cells are regarded as degenerating-cells, others (*Neumann*) look upon them as representing a stage in the development of proliferating cells, while others still (*Ehrlich*, *Rosenheim*, *Korybutt-Daszkiewicz*) believe that they are simply cells which have received an excess of nutriment.

*Arnold* regards the cell-granules which may be demonstrated by means of especial stains in leucocytes, pus-corpuscles, bone-marrow cells, and also in other cells, not as granules of secretion, but as representing changed structural elements of the cells arising out of a metamorphosis of the plasmosomes—that is, the microsomes of the cell-cytoplasm (see § 81). Acidophile cells may be transformed into basophile, or the reverse may occur; these phenomena are to be regarded as the expression of different stages of development with changes in the physico-chemical properties.

The formations described in §§ 65 and 66 as *connective-tissue hyalin* are undoubtedly pathological products, which differ from each other in so far as their mode of origin and their chemical composition are concerned. Since we do not yet know the nature of the processes leading to these hyaline formations, there is nothing to do but to group them according to definite points of view.

*Von Recklinghausen* gives to the term *hyalin* a much more comprehensive meaning than I do. He includes under the head of hyaline degeneration different pathological changes which I have placed under other heads. He defines hyalin as an albuminous body which stains intensely with eosin, carmine, picrocarmine, and acid fuchsin; is homogeneous and strongly refractive; is but slightly changed by acids; and in its resistance to alcohol, water, ammonia, and acids resembles amyloid, but does not give the iodine reaction. As hyalin he includes epithelial colloid and the hyaline products of connective tissue cells, as well as hyaline degeneration of the ground substance of the connective tissue, also hyaline thrombi, and the hyaline coagula of inflammatory exudates, and hyaline tissue-necroses. According to this author, all these formations result from the fusion of the elements of neighboring cells. From their external appearance, all these products may be properly designated *hyalin*; but the following varieties must be recognized: *epithelial hyalin* (colloid, keratohyalin), *connective-tissue hyalin* (hyaline degeneration of the ground-substance of connective tissue, hyaline products of cells, and cells which have become hyaline), *blood-hyalin* (hyaline thrombi), *exudative hyalin* (hyaline coagula of exudates on mucous membranes, serous surfaces, inflamed connective tissue, in the urinary tubules, tubercles, etc.), and *hyaline tissue-necroses*. In the case of connective-tissue hyalin a distinction must be made between the hyalin formed as a secretion in the cells (closely related to epithelial colloid, in its mode of origin), and hyaline degeneration of the ground-substance of connective tissue.

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See also § 65.

### XIII. Petrification of the Tissues and the Formation of Concretions and Calculi.

§ 67. It is, on the whole, of rather frequent occurrence for firm crystalline, or amorphous, granular masses to be deposited in various parts of the body-tissues; and when such deposits are of such extent as to

cause hardening of the affected tissue, the resulting condition is known as **petrification**, or when the deposit consists of lime-salts (particularly phosphates) as **calcification**.

The deposit may occur, in the first place, in a tissue which forms an integral element of an organ, and which bears its normal relation to the surrounding tissues. In other cases it takes place in portions of tissue which have been loosened from their surroundings; or insoluble substances which have become changed into a firm state; or, finally,

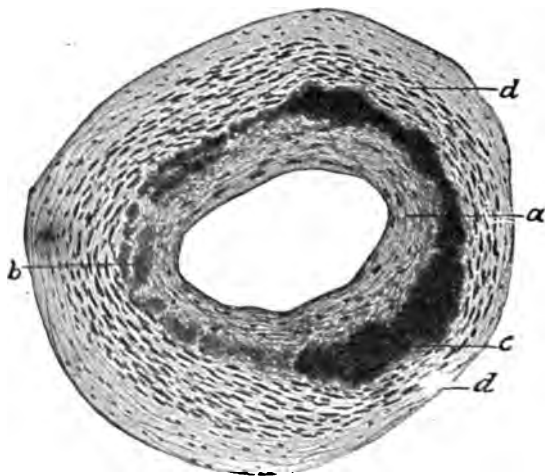


FIG. 87. Sclerosis and calcification of a uterine artery. (Formalin, hematoxylin, and eosin.) *a*, Sclerotic intima; *b*, *c*, calcification; *d*, media.  $\times 50$ .

ly, in foreign bodies which have entered the body from without, and form the centres of a process of incrustation.

In the first case there arise **petrifications of the tissues**; in the second, **free concretions and calculi**. It is to be noted, however, that un-

der certain conditions free concretions may become firmly attached to the tissues of the organ in which they lie, by means of tissue-proliferations extending into or surrounding them. On the other hand, a calci-



FIG. 88.

FIG. 88.—Calcification of the media of the aorta.  $\times 350$ .

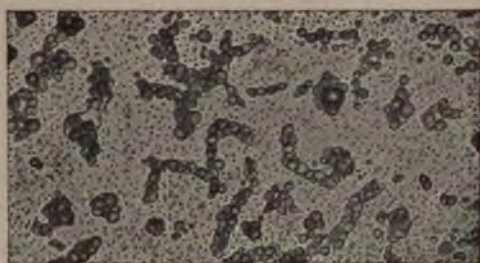


FIG. 89.

FIG. 89.—Calcified vessels in the cerebellum. (Alcohol, hæmatoxylin.)  $\times 100$ .

fied portion of tissue may in the course of time gradually become loosened from its surroundings and ultimately form a free concretion.

The cause of tissue-petrification is to be found chiefly in local tissue-changes, in that the deposit of lime-salts usually occurs in places where the tissue has already died, or is in process of degeneration and necrobiosis. It would seem that dying tissue, which has undergone more or less modification, possesses a certain attraction for the lime-salts held in solution in the body-fluids, and enters into close combination with them. Among dead or degenerating tissues which yet remain attached to their neighboring structures those which have undergone hyaline degeneration are especially subject to calcification; particularly the hyaline, sclerotic connective tissue (§ 65), which either contains but few nuclei or none at all, such as is not infrequently found in the blood-vessel walls (Figs. 87, *b*, *c*, and 88), in the endocardium, in enlarged and degenerated thyroids, or in thickenings of the pleura and pericardium. Further, lime-salts are frequently deposited in degenerative areas in the vessel-walls, or in tumors, or in any other portion of the body, in association with fatty or hyaline degeneration; in degenerating cartilage; in degenerating or necrotic cells, as, for example, in ganglion-cells or kidney epithelium (von Kossa), or in liver-cells (in poisoning with mercuric chloride, lead, aloin, bismuth [Fig. 90, *d*, *e*], copper-salts, iodine, and iodoform [von Kossa]); or in extensive areas of necrosis in inflammatory proliferations.



FIG. 90.—Calcification of the epithelium of the kidney-tubules following sublimate poisoning. (Alcohol, hæmatoxylin.) Patient died seven days after the poisoning. *a*, Normal tubules; *b*, tubule with desquamated epithelium; *c*, tubule with desquamated and necrotic epithelium possessing no nuclei; *d*, *e*, tubule with degenerated and calcified epithelium.  $\times 300$ .

In rare cases there may occur a deposit of lime-salts in organs which show but slight changes—for example, in the lungs. Since in part of such cases there is found at the same time a more rapid absorption of the skeleton (senile atrophy of the bones, destruction of the bones by tumors), this deposit is regarded as metastatic in nature, due to the overloading of the blood with lime-salts. Even under these circumstances the immediate cause of the calcification is local, and is dependent upon retrogressive changes—in the lung tissue (senile atrophy, obliteration of vessels, venous congestion); and the increased absorption of the skeleton is but a favoring factor. According to investigations by Kockel the elastic lamellæ of the small and medium-sized vessels in particular become calcified, but the elastic fibres and capillaries of the alveolar septa are also involved.

The lime-salts are first deposited in the tissue in the form of small granules (Fig. 88); and preparations may occasionally be obtained in which the separate calcareous granules are yet distinctly visible.

Through the confluence of such granules larger clumps and spherules are formed (Fig. 89). More frequently, however, there results a more

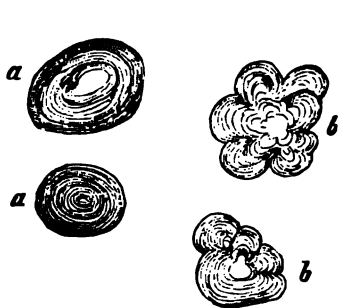


FIG. 91.

FIG. 91.—Calcareous concretions. *a*, Concretions from an inflamed omentum; *b*, calcareous masses from a tuberculous lymph-gland which had undergone caseation.  $\times 200$ .

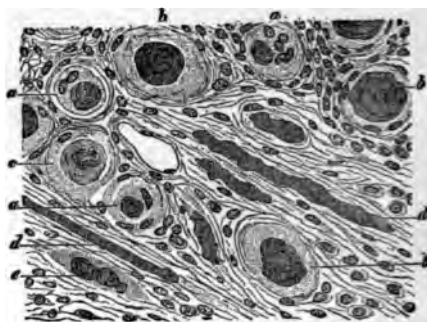


FIG. 92.

FIG. 92.—Section from a psammoma of the dura mater, with concretions. (Alcohol, picric acid, hæmatoxylin, eosin.) *a*, Hyaline nucleated spherule with enclosed calcareous granule; *b*, calcareous concretion with hyaline non-nucleated capsule, embedded in fibrous connective tissue; *c*, calcareous concretion surrounded by hyaline connective tissue; *d*, calcareous spicule in connective tissue; *e*, calcareous spicule containing three separate concretions, embedded in the connective tissue.  $\times 175$ .

homogeneous deposit, in which it is impossible longer to distinguish the individual granules.

The calcification may affect both the cells (Fig. 90, *d*, *e*) and intercellular substance (Figs. 87, 88, and 89). During the process of calcification the degenerated tissue shows different reactions toward certain stains from that exhibited by unchanged intercellular substance or living cell-protoplasm, in that the area of calcification stains a dark bluish violet with hæmatoxylin (Fig. 87, *b*, *c*, *d*; Fig. 90, *d*, *e*), and red with picrocarmine. This applies, however, only to deposits of carbonates and phosphates of lime, but not to those of calcium oxalate. According to von Kossa, the presence of calcification may be also demonstrated by means of dilute solutions of silver nitrate, a black color being produced during the formation of silver phosphate from the organic constituents remaining in the granules of calcium phosphate.

Calcification may affect small or large areas of tissue, causing in the

latter case a hardening and whitish coloration of the tissue. At times the areas of calcification may appear as sharply circumscribed spherical or nodular masses (Fig. 91 and Fig. 92, *a, b, c*), or long spicules (Fig. 92, *d*) or cactus-like formations. In this manner there are produced concretions lying in the tissues, and these not infrequently may be recognized by the naked eye. Under physiological conditions such concretions in the form of laminated calcareous spherules occur particularly in the pineal gland and the choroid plexus (the so-called *brain-sand*, *acervulus cerebri*). As pathological formations they are found in different parts of the pia and dura mater; in many tumors of the same (psammoma or sand-tumors, Fig. 92), also in areas of caseation (Fig. 91, *b*), or in thickened connective tissue (Fig. 91, *a*). The origin of these formations may be studied to the best advantage in the psammomata. In general they arise through the conversion of tissue-cells (Fig. 92, *a, b, c*) or fibrous connective tissue (*d*) into hyaline masses, at first containing nuclei (*a*) but later showing none (*b, e*), these masses then taking up lime-salts. Spherical concretions arise in particular from hyaline masses of cellular origin (*a, b, c*); the spicules (*d*) from hyaline connective tissue, though spherical concretions may be formed also in hyaline connective tissue (*e*). The connective tissue which undergoes hyaline degeneration and calcification is for the chief part ordinary fibrous tissue, but the spicules of lime-salts and round concretions may be formed also in the vessel walls.

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See also § 69.

§ 68. The more common petrifications consist of deposits of phosphate of lime, sometimes of carbonate; with these some magnesium salts may be mixed. Under especial conditions there occur also **deposits of uric-**



FIG. 93.—Deposits of urates in the knee-joint, in a case of gout. *a*, Condyles of the femur; *b*, urate deposits on the cartilage. Two-thirds natural size.

**acid salts**; particularly in the disease known as **gout**, which is a chronic disturbance of the general nutrition characterized by a *uric-acid diathesis* leading to a deposit of uric acid in the tissues.

Gout is usually inherited, and but rarely acquired; it occurs most frequently in certain regions, as, for example, in England and in North Germany; and is very rare in other countries, as in South Germany. Of the ultimate cause of the disease we have as yet no positive knowledge. It is characterized chiefly by the deposit in the body of uric-acid salts, chiefly sodium urate, with which small quantities of carbonate and phosphate of lime are sometimes associated (Fig. 93, *b*). The deposit of these salts takes place usually during acute, typical paroxysms characterized by pain and inflammation, but very great departures from a typical course may occur. The deposits are found in the kidneys, skin,

subcutaneous tissue, tendon sheaths, tendons, ligaments, bursae, and articular cartilages (Fig. 93), but may finally be present in almost all the organs. The metatarsophalangeal joint of the great toe is a favorite site of deposit, and often the first part affected. The deposits consist essentially of clusters of fine slender needles (Fig. 94), in whose neighborhood the tissues are degenerated or necrotic; and

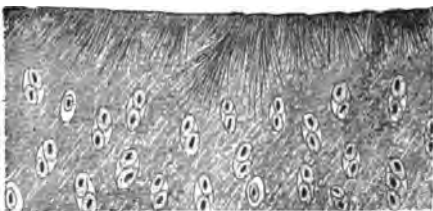


FIG. 94.—Deposits of needle-shaped crystals of sodium urate in the articular cartilage. (After Lancereaux.)  $\times 120$ .

from this it may be assumed that the urates entering the tissues in solution give rise to the necrotic changes in the latter.

The areas of necrosis and incrustation are at first of small size, but occasion inflammation and tissue-proliferations in their neighborhood. Later, with the occurrence of other paroxysms the deposits become larger, so that *large nodules* (the so-called *tophi*) are formed. These consist of white, plaster-like masses, and under certain conditions may form marked nodular thickenings in the joints and tendons (Fig. 95).

In the joints the articular cartilages at first appear as if sprinkled over with plaster-of-Paris (Fig. 93, *b*), but later the white masses penetrate deeper and may permeate the entire articular cartilage. In the kidneys the tissue-necrosis caused by the uric acid, and the resulting inflammation may lead to contraction and induration of the organ. The deposit affects chiefly the medullary pyramids, but is found also in the cortex.

According to Garrod and Ebstein the acute paroxysms in gout depend upon an excessive accumulation of uric acid, either as the result of deficient excretion by the kidneys (Garrod) or of local changes (Ebstein). According to Pfeiffer the gouty predisposition is due essentially to the fact that the uric acid in the body-fluids is produced

in a form which is soluble with difficulty, and tends to be deposited in the tissues where it may collect in such quantity as to cause a localized necrosis. The symptoms of the gouty paroxysm are supposed to depend upon an increased alkalinity of the body-fluids caused by especial conditions, as a result of which there follows a partial solution of the deposited uric acid, in the course of which process attacks of pain and symptoms of inflammation are produced. On the other hand, von Noorden regards the formation and deposit of uric acid as a secondary process, due to the local action of a special ferment, and quite independent of the amount and condition of the uric acid in other parts of the body.



FIG. 95.—Gouty nodes of the hand. (After Lancereaux.)



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§ 69. **Free concretions** are formed in the first place in the various ducts and cavities of the body which are lined by epithelium, as in the intestines, in the ducts of the glands pouring their secretions into the intestine, in the gall-bladder, urinary passages, and respiratory tract. In a certain sense the concretions formed in the blood-vessels and serous

cavities might also be included in this group, although they are for the greater part firmly united to the surrounding tissues.

All free concretions possess an organic base or nucleus. Thus *enteroliths* which form in the intestines have a nucleus of inspissated feces, or foreign bodies which have been swallowed, such as hairs (*bezoar stones* or *ægagropilæ*), or indigestible portions of vegetable food, etc., in and about which phosphates (ammonium - magnesium phosphate and calcium phosphate), and carbonates are deposited in varying proportions according to the nature of the food ingested. In the mouth-cavity incrustations of the teeth, known as *dental calculi* or *tartar*, are formed by the deposit of lime-salts in masses consisting of mucus, cell-detritus, and bacteria. In the same way there are formed in the *ducts of the salivary glands and pancreas* oval or spherical faceted, or irregularly nodular, glandiform *concretions*, through the calcareous impregnation of a substance derived from the epithelium of the gland.

*Bronchial calculi* are formed by the calcification of thickened bronchial



FIG. 96.—Faceted stones from the gall-bladder. Natural size.

secretion; the *stones found in veins and arteries* (phleboliths and arterio-liths) from the calcification of thrombi; *prostatic calculi* through the calcification of the so-called amyloid concretions; *navel stones* through the retention and incrustation of desquamated epithelium, hairs, and other substances which may enter the navel-depression.

The *biliary calculi* and *gall-stones* found in the bile passages and gall-bladder are in part small granules, and partly larger spherical, oval, or faceted stones (Fig. 96), which on fracture appear to consist purely of crystalline masses. By the employment of proper methods it may be shown that these stones also possess a nitrogenous ground-substance.

According to their essential composition gall-stones may be classed as cholesterin, cholesterin-pigment, bilirubin, biliverdin-calcium, and calcium carbonate stones. The first two varieties are the most common; they present a rayed, crystalline, often laminated fracture; and vary in color and in their mottling according to the amount of bile-pigment present. When no pigment is

present they may be colorless and translucent.

If the cholesterin be dissolved out of a cholesterin stone by some suitable method, it will be found that the form of the stone is preserved, and a delicate, for the greater part yellowish, mass remains. This, when carefully embedded and cut into sections, is found under the microscope to consist of a delicate, homogeneous substance (Fig. 97) which shows concentric stratification and radiating clefts or spaces which were formerly occupied by the crystalline masses. A similar ground-substance may be demonstrated in other calculi after solution of their calcium salts.



FIG. 97.—Section through a small cholesterin stone after removal of the cholesterin.  $\times 13$ .

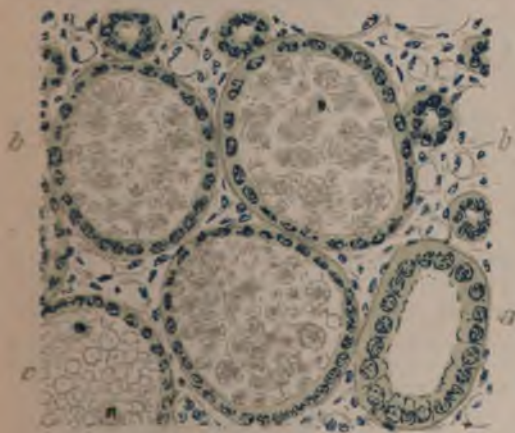


FIG. 98.—Uric-acid infarct of the new-born. (Alcohol, hæmatoxylin. Drawn from a preparation that had been washed in water.) Transverse section through the pyramid of the kidney. *a*, Transverse section of unchanged collecting tubule from the papilla; *b*, dilated collecting tubule filled with uric-acid concretions; *c*, remains of concretions after washing with water.  $\times 200$ .

There can, therefore, be no doubt that gall-stones are also the result of the incrustation of an organic substratum, which is in all probability derived from the mucous membrane of the biliary passages and the gall-

bladder. Gall-stones occur especially in advanced years; stagnation of the bile favors their formation. Inflammations of the mucous membranes of the bile-passages (angiocholitis) lead to desquamation and destruction of the epithelium (eventually also to escape of leucocytes), and in the products derived from these pathological changes bilirubin and cholesterolin are deposited. When once a concretion is formed it increases in size through the deposit of new products of cell-disintegration which become encrusted with cholesterolin, pigment, and calcium. According to Naunyn the originally soft nucleus of the concretion undergoes a change, in that it separates into firm, granular masses of pigment-calcium and crystals of cholesterolin which are deposited upon the outer crust, and into fluid, so that the stones may at times contain a cavity filled with fluid. In the course of time this cavity may again be filled with cholesterolin; and also the pigment and calcium in the remaining portions of the stone



FIG. 99.



FIG. 100.

FIG. 99.—Coral-shaped stone from the bladder, composed of calcium oxalate and phosphate. Natural size.

FIG. 100.—Transverse section of two stones from the bladder, closely fitted together, and consisting of sodium urate and ammonium-magnesium phosphate. Natural size.

may be gradually replaced by cholesterolin. Further, calcium carbonate may also be deposited.

The cholesterolin masses from which the concretions are formed are derived chiefly from the disintegration of epithelial cells; likewise, the lime-salts combining with bilirubin are also furnished by the mucous membrane.

As Ebstein has shown, the *urinary calculi, gravel, and stones* are also composed of an organic ground-substance, an albuminous stroma, in which the various constituents of the urine may become deposited. According to location we may distinguish calculi of the kidney and those of the descending urinary passages. In the kidneys the deposits may form only small granules lying in the tissue itself, or in part also free in the lumen of the urinary tubules, in the latter place lying in the products derived from the disintegration of necrotic epithelial cells. This is true in the first place of the calcifications which, as mentioned above, occur in the necrosed renal epithelium after poisoning with corrosive sublimate, bismuth, aloin, copper-salts, iodine, phosphorus, potassium chromate, and oxalic acid. The same thing is true of some of the gouty deposits. Finally, belongs here the so-called *uric-acid infarct of the new-born*, a con-

dition characterized by the appearance of yellowish-red stripes in the medullary pyramids. The condition is not infrequently seen in children dying during the first five weeks after birth. The epithelium of the tubules is usually well preserved, but in places desquamation and disintegration of single cells may be found. The lumina of the tubules are filled with very small, colorless or yellow granules of urates or uric acid, which at times show fine radiating lines (Fig. 98, *b*). On solution of these granules a delicate stroma remains (*c*). If as the result of the presence of the infarct further changes in the epithelium of the tubules are produced, leading to the formation of albuminous material in the tubules, single granules may under certain conditions develop through accretion into large stones, but this occurrence is rare.

In the pelvis of the kidney, ureters, urinary bladder, urethra, and under the prepuce concretions may be formed, either as sand, gravel, or stones. The last-named are oval or spherical, and may be smooth or rough and nodular, not infrequently resembling a mulberry or mass of coral (Figs. 99 and 100). When several stones lie closely together, their surfaces may become faceted (Fig. 100). Those found in the kidney pelvis may form casts of the cavity and of the calyces.

When examined in section, urinary calculi are sometimes homogeneous, at other times distinctly stratified (Fig. 100) or show radiating lines. Not infrequently there may be seen a nucleus and several zones of different appearances. The crystalline masses lie partly in the spaces of the stroma, and partly in the latter itself; and it may, therefore, be assumed that the stroma is a product of the mucosa of the urinary passages, and that its formation follows catarrhal inflammations or toxic necroses of epithelium when these lead to the collection of mucus or cell-detritus in the tubules.

What substances are deposited in a given case in the products of the mucous membrane depends upon the existing conditions. When the conditions favoring stone-formation are associated with a uric-acid diathesis, or if the excretion of uric-acid salts by causing tissue-necrosis has at the same time produced the conditions favoring the development of concretions, the deposits in the organic ground-substance will consist chiefly of urates. Decomposition of the urine with formation of ammonium-magnesium phosphates leads to the production of calculi consisting chiefly of this substance. Cystin calculi may be formed when cystin is excreted by the kidneys, as the result of peculiar metamorphoses of albumin in the intestine, due to the action of bacteria (Baumann, von Udransky, Brieger). When once a stone is formed, the irritation which it causes upon that portion of the mucous membrane with which it comes in contact, as well as the decomposition of the retained urine, favors its further growth by accretion. Likewise, *foreign bodies* (Fig. 101), which have in any way entered the bladder



FIG. 101. — Incrustated lead-pencil, 12 cm. long, taken from the male urinary bladder. Reduced  $\frac{1}{2}$ .

from without, may lead to the formation of calculi, through the irritation which they excite in the mucous membrane of the bladder.

Intestinal calculi are much more common in horses and cattle than in man; since undigested vegetable material and hairs which have been licked off are of frequent occurrence in the intestinal canals of these animals and form the starting-point of such concretions. The true stones, which occur especially in horses, are rather hard masses consisting chiefly of magnesium phosphate; the false stones consist of hairs and vegetable fibres which are more or less encrusted. Occasionally balls are found which consist almost wholly of hair (*agagropili* or *bezoar stones*). In ruminating animals they are found chiefly in the rumen or reticulum; in hogs, more frequently in the small intestine.

According to *Schuberg*, the enteroliths of herbivorous animals consist chiefly of carbonates; those of carnivorous, of phosphates. The composition of those found in man varies according to the food ingested.

Urinary calculi are classified according to their composition as follows:

1. *Calculi composed chiefly of uric acid or urates.*

Pure uric-acid calculi are usually small, yellow, reddish, or brownish in color, and hard.

*Stones consisting of urates* are rarely pure. They are usually covered on the surface with a coating of calcium oxalate and ammonium-magnesium phosphate.

2. *Calculi composed chiefly of phosphates and carbonates.*

To this class belong stones composed of calcium phosphate, ammonium-magnesium phosphate, and calcium carbonate. The last two varieties are rare. All these calculi are white or grayish-white. The triple phosphate stones are soft and friable, the others hard.

3. *Stones composed of calcium oxalate.*

These are hard and rough, and of a brown color.

4. *Cystin calculi.*

These are soft, waxy, and of a brownish-yellow color.

5. *Xanthin calculi.*

These are cinnabar-red in color, smooth, and have an earthy fracture.

*Ebstein* and *Nicolaier* succeeded in experimentally producing urinary calculi by feeding animals with oxamide, an ammonium derivative of oxalic acid. The greenish-yellow concretions thus produced in the urinary passages of dogs and rabbits consisted essentially of oxamide; on section they presented a concentric laminated structure showing radiating striations. They were found likewise to possess an albuminous stroma, which was derived from the necrosis and desquamation of epithelium caused by the action of the oxamide during excretion.

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#### XIV. The Pathological Formation of Pigment.

§ 70. Both connective and epithelial tissues in various parts of the body contain normally an **autochthonous pigment**, which *lies within the cells*, and consists either of yellow, brown, or black granules, or forms a diffuse yellow or brown coloration of the cells. These autochthonous pigments are known as **melanin**, **lipochrome**, and **hæmofuscin**. In the epithelial tissues the pigment is found particularly in the lowest layers of the rete Malpighii, which contains pigment in all the pigmented portions of the skin, also in the hairs, in the pigment-epithelium of the retina, and in many ganglion-cells. In the pigment-cells of the skin the granules are chiefly yellow and brown; in the epithelium of the retina they are black. In marked pigmentation of the skin other cells besides those of the rete Malpighii contain pigment. Among the connective-tissue cells, which most frequently contain yellow or brown pigment-granules, are the cells of the choroid, sclera, corium, heart-muscle, muscularis of the intestine, and pia.

The **normal autochthonous pigments may be increased** under various physiological and pathological conditions. For example, *during pregnancy the pigment of the skin is usually more or less increased (chloasma uterinum)*, particularly in brunettes. In *Addison's disease*, a general disease leading to cachexia and which is dependent upon pathological conditions of the adrenals (see § 27), there occurs a decided pigmentation of the skin as a result of an increase of the normal pigment. Not infrequently spots of a bronze color appear in the mucous membranes of the mouth. Further, in atrophic conditions of the heart there is usually an increase of the **normal heart-pigment**. Yellow pigment-granules also



FIG. 102.—Large hairy pigmented mole over the back and buttocks, with scattered spots of pigmentation over trunk and shoulders. (After Röhrling.)

appear in the *voluntary muscles* in conditions of atrophy; and in old persons the *smooth muscle of the intestine* always contains more or less of a yellow granular pigment, so that sometimes the outer surface of the intestine may show a yellow or yellowish-brown coloration.

The most intense grades of pathological pigmentation are met with in *freckles*, *lentigines*, *pigmented moles* (Fig. 102) and *pigmented warts*, and in *black melanotic tumors* (see Chapter VIII.). The amount of pigment may be so great as to give the tissues a pure black color.

The pigment lies for the greater part inside of tissue-cells (*chromatophores*), more rarely in the intercellular substance. It is composed of yellow, brown, or black granules; not infrequently individual cells may be diffusely pigmented. In Addison's disease the pigment-granules are found partly in epithelial cells, especially in those lying directly upon

the connective tissue (Fig. 103, A, a, b, and B, a), and partly in branched connective-tissue cells (A, c, c<sub>1</sub>, d), from which pigmented processes extend up between the epithelial cells (B, c).

In the pigmented spots of the skin and in melanotic sarcomata the pigment is partly contained in especially differentiated connective-tissue cells of large size, and partly in apparently normal cells of the given tissue, very often in the connective-tissue cells in the neighborhood of the vessels and in the cells of the vessel-walls.

In the ganglion-cells the pigment is composed of brown granules.

*The pigments just described are products of a specific cell-*

*activity*; and we must suppose that many connective-tissue cells, ganglion-cells, and muscle-cells are able to form pigment from the material brought to them. In the majority of cases the pigment appears to be formed in the places where it is found; yet different investigations make it probable that the pigment may at times be transported. The pigment of the epidermis and of the hairs, at least in part, is not formed in the epithelial cells themselves, but in branched connective-tissue cells (Fig. 103 A, c, d, and B, c) which lie just beneath the rete, and send processes between the epithelial cells, through which the pigment is transferred to the latter.

The fact that the pigment is often found particularly about the blood-vessels would seem to indicate that the material from which it is formed is derived from the blood, and many authors accept without question the view that the pigment is a derivative of the coloring-matter of the blood. Against this view is the fact that neither in the blood nor in the neighborhood of the blood-vessels are there present evidences of an escape of the red blood-cells or of a disintegration and solution of the same. It

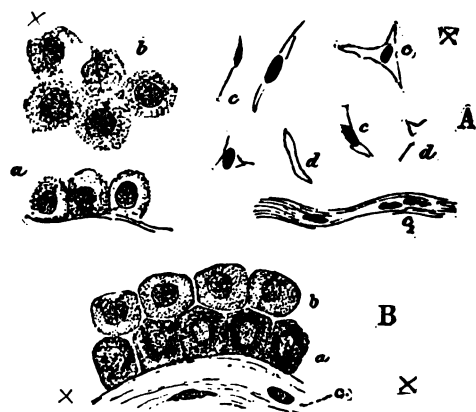


FIG. 103. A and B. Pigmented cells of the skin from a case of Addison's disease with caseous tuberculosis of both adrenals. (Alcohol, carmine.) a, Pigmented epithelial cells from the deepest layer, in a section cut at right angles to the surface. A, b, Pigmented epithelial cells from a section made parallel to the surface. B, b, Epithelial cells containing no pigment; c, c<sub>1</sub>, nucleated pigmented connective-tissue cells, the processes of which, in B, push between the epithelial cells; d, pigmented cell-processes.  $\times 350$ .

is, therefore, very probable that the pigment is formed either from the circulating albumin or from the albumin of the cells.

The attempt has been made to solve this problem by means of chemical investigations; and the results obtained up to the present time favor the theory that the pigment is a product of cell-activity, and is formed from albuminous bodies. The different forms of **melanin**, in which group the pigments of the skin and choroid are usually placed, are, according to the investigations of von Nencki, Sieber, Abel, Davids, and Schmiedeberg, nitrogenous bodies rich in sulphur, but vary greatly in composition. According to Schmiedeberg these differences depend upon their mode of origin, inasmuch as these pigments represent the *final product of a long series of metamorphoses of albumin*; and in their formation may be compared to the development of humus. The genuine albuminous bodies do not furnish the material for the building up of this final product (Schmiedeberg), but it is derived from sulphur-containing bodies formed by the splitting-up of the albumins, and from which certain carbon-containing groups have already been split off, so that there arise combinations which in proportion to their carbon-content are very rich in sulphur, and from these the melanins are formed.

The majority of authors regard melanin as an iron-free substance. Brandl, Pfeiffer, Mörner, and others, on the other hand, found small quantities of iron in melanosarcomata; but this cannot be regarded as a proof that the melanin was derived from hæmoglobin, inasmuch as a tumor may contain besides melanin also iron-containing products arising from the disintegration of red blood-cells. The majority of the pigment granules give no reaction for iron.

**Lipochrome** is the term applied to the coloring-matter of adipose tissue, corpora lutea, ganglion-cells (Rosin), and of the greenish tumors known as chloromata (Krukenberg). Of the origin and nature of this pigment nothing definite is known.

**Hæmofuscin** (von Recklinghausen, Goebel) is the iron-free, yellowish, granular pigment found in heart-muscle, smooth and striped muscle, in the cells of the glands of the stomach and intestine, in the lachrymal, mucous, and sweat glands. According to von Recklinghausen this pigment is derived from the blood, but it has not yet been established that it is a hæmoglobin-derivative. The sulphur-content (Rosenfeld) makes it not unlikely that the hæmofuscin granules belong to the melanin group.

*Aeby* was the first to express the belief that the epithelial cells themselves do not form the pigment, but obtain it from wandering cells which penetrate between the individual epithelial cells and there degenerate, the pigment and cellular debris being taken up by the epithelium. According to *von Kölliker*, "the pigment of the hair and epidermis is derived from pigmented connective-tissue cells which lie just beneath the deepest layers of the epithelium of the hair-bulbs and of the rete, and send processes between the delicate cells of these layers. These processes divide into long fine ramifications which lie in the intercellular spaces and may even penetrate into the cells themselves, and in this way transfer their pigment to the latter." The pigment of the ganglion cells and of the cells of the retina arises, on the other hand, in the ectodermal cells themselves. *Richt* and *Ehrmann* agree with *von Kölliker*. *Karg* observed that, following the transplantation of white skin on to the surface of a leg-ulcer in a negro, the white grafted portions became wholly black in from twelve to fourteen weeks; and he concludes that, in the pigmentation of the epidermis, pigmented connective-tissue cells penetrate between the epithelial cells and convey pigment to the latter. Microscopical examination showed the presence of such pigmented processes between the epithelial cells at a time when the latter had not yet become pigmented. *Von Wild* has shown that in melanosarcomata of the skin pigmented connective-tissue cells may penetrate between the epithelial cells. Similar pigmented connective-tissue cells are found in the



pigmented portions of the skin or mucous membranes in cases of Addison's disease, usually, however, in certain areas only and not everywhere.

Histological studies of the mode of formation of the normal pigment in various animals, chiefly in fishes, amphibia, and reptiles, have led to different conclusions. Thus *Jarisch* is of the opinion that the pigment of the skin and teeth of tadpoles is not derived from the blood, but is a product of the protoplasm, while *List*, on the other hand, believes that the pigment of the skin of fishes and amphibia is formed from hæmoglobin. *Ehrmann* holds that the melanotic pigment of all vertebrates is a hæmoglobin-derivative. According to *Kromayer*, the pigment of the skin of mammals is derived from the protoplasmic fibrillæ (spongioplasm) and represents a degeneration-product of the same.

In domesticated animals there occurs a peculiar **melanosis of the internal organs**, occasionally associated with melanosis of the subcutaneous tissue. The affected organs (heart, lungs, intestines, etc.) present in varying numbers grayish or black spots, looking like ink-spots, which are produced by the deposit of pigment in connective-tissue cells which otherwise appear normal.

Under the term **ochronosis of cartilage**, *Virchow* described a peculiar iron-free pigmentation of the cartilage, tendon-sheaths, and capsules of the joints, in which the cartilage shows a brown or black color, caused by the imbibition by the ground-substance of some pigment. *Virchow* believed the condition to be due to the imbibition of blood-pigment, and compares the process to the pigmentation of freckles and lentigines. It is probable that the condition is a more pronounced form of the *brown pigmentation*, which occurs especially often in the costal cartilage of old persons. Occasionally the pigment is deposited in a granular form, and may be found as granules within the cells. Of the nature of the pigment and its origin nothing is known; it probably belongs to the melanin group.

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§ 71. **Hæmatogenous pigments**—that is, *the pigments whose origin from the coloring-matter of the blood may be demonstrated beyond any doubt*—are derived usually from blood which has escaped from the blood-vessels, or has undergone coagulation within the vessels, and are, therefore, *dependent upon local changes*. In other cases they may be caused by a taking-up of blood-pigment into the blood or by a change in the blood itself, whereby granular pigment is either formed in the blood, or hæmoglobin passes into the blood-plasma, so that pigmentation of the tissues results from *metastatic deposits of pigment*. Such pigmentations are known as **hæmachromatoses**.

Both large and small **extravasates of blood** very soon undergo certain changes which are visible to the naked eye. Extravasates in the skin become first brown, then blue, followed by green, and finally yellow. Small hæmorrhages into the tissues, as in the peritoneum, pleura, and lungs, may show for a long time as reddish-brown spots; in decomposing cadavers their color may be slate-colored or black. Large hæmorrhages into the tissue, as in the brain or lungs, assume after a certain time a rust-brown color, which later changes to an ochre-yellow, yellow, yellowish-brown, or brown pigmentation. All these changes of

color correspond to certain changes in the hæmoglobin and in the iron which it contains.

Whenever a **hæmorrhage** occurs in the tissues or into a body-cavity, a certain portion of the blood-plasma and of the *red blood-cells* may be taken up *unchanged* through the lymph-vessels. Another portion of the corpuscles gradually loses its hæmoglobin, the pale stroma of the corpuscles remaining. The *escaped hæmoglobin* diffuses through the surrounding

tissues, and from it there are formed the different products which give rise to the changes of color in the neighborhood of the extravasate. A part of the absorbed hæmoglobin may be excreted as *urobilin* (*urobilinuria*); another part, on the other hand, may be precipitated in the tissues in the form of granules or crystals. The latter are *yellowish-red or ruby-red rhombic plates and needles of hæmatoidin* (Fig.

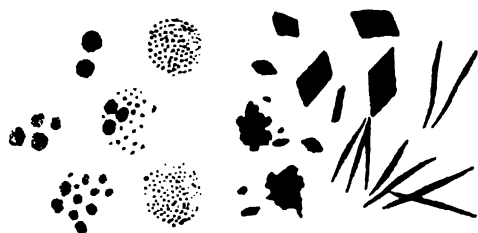


FIG. 104.—A, Cells containing amorphous blood-pigment: a, those with few large fragments of red blood-cells; b, c, those containing great numbers of small disintegration-products of red blood-cells; B, rhombic plates and needles of hæmatoidin.  $\times 500$ .

104 B); and represent a frequent residuum of hæmorrhages. A portion of the diffused hæmoglobin may also be taken up by cells, the latter thereby acquiring in part a diffuse yellowish pigmentation, or in part showing the presence of yellow and brown pigment-granules.

A third portion of the blood-corpuscles disintegrates at the site of the extravasation, and forms *yellow and brown granules and lumps*. This event occurs particularly in larger extravasates in the so-called *hæmatomata*. The pigment-granules and lumps which arise either directly from the disintegration of red blood-corpuscles, as well as the crystals and granules precipitated from the dissolved hæmoglobin, are often taken up by cells, partly leucocytes and partly cells derived from proliferating tissue; and these form the so-called *blood-corpuscle cells* and *pigment-containing cells* (Figs. 104, A and 105, a, b).

At the beginning of the disintegration of the red corpuscles the coloring-matter present is hæmoglobin, but this quickly undergoes changes; and the yellow and rusty masses and granules which are found both in the cells and lying free, and which become changed in the course of time into darker pigment, are no longer hæmoglobin itself, but represent different **derivatives of hæmoglobin**. According to their chemical composition these derivatives may be divided into two groups, one iron-free, the other containing iron. The former is known as *hæmatoidin*, the latter as *hæmosiderin* (Neumann).

**Hæmatoidin** (*identical with bilirubin*) is a ruby-red (Fig. 104, B) or reddish-yellow (Fig. 105, b) pigment occurring either in crystalline form, or as granules, which may be amorphous, but often show a somewhat angular shape (Fig. 105, b), suggesting rudimentary and imperfect crystals. Hæmatoidin is soluble in chloroform, carbon disulphide, and absolute ether; and insoluble in water and alcohol. It would appear to be formed especially when hæmoglobin is but slightly exposed to the action of living cells, as is especially the case in the centre of large extravasates and in hæmorrhages into the body-cavities, as, for example,

into the pelvis of the kidney or the subdural space. It may be produced artificially by the introduction of glass capsules containing blood beneath the skin or into the peritoneal cavity in such a way that the blood within the capsules may be exposed to the action of the tissue-fluids but not of the cells.

The granules and crystals of hæmatoidin are found in the tissues either free (Fig. 104, B), or enclosed in cells (Fig. 105, *b*). In the latter case the granules and crystals are usually taken up by phagocytes after they have been formed; though occasionally it may happen that the hæmatoidin while in solution is taken up by fixed connective-tissue cells, for example, cartilage or fat-cells, and then precipitated in solid form.

**Hæmosiderin**, the derivative of the red blood-cells which contains iron in demonstrable quantity microscopically, is usually found in the tissues as yellow, orange, and brown granules and lumps which become darker in the course of time. They are for the greater part contained within cells, and in part are formed within the cells.

When treated with potassium ferrocyanide and dilute hydrochloric acid hæmosiderin becomes deep-blue through the formation of Berlin blue (ferric oxide salt of hydroferrocyanic acid) (Fig. 105, *a*). When treated with ammonium sulphide there is formed a black sulphide of iron.

Hæmosiderin appears to be formed particularly (Neumann) when the blood in an extravasate or in a thrombus is subjected to the action of cells; and it is consequently seen more frequently in small extravasates and at the periphery of larger ones. The formation of hæmosiderin may take place either within the cells or free in the tissue. The pigment enclosed within cells (sideriferous cells) may have been formed from the

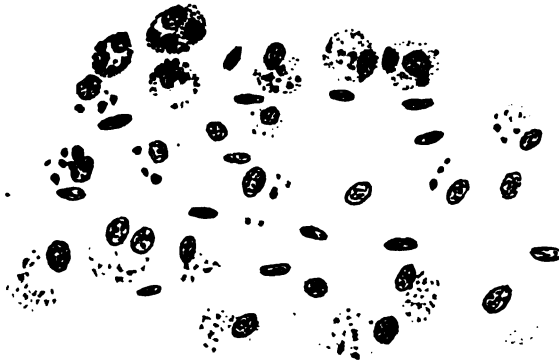


FIG. 105.—Cells containing hæmosiderin and hæmatoidin from an old hæmorrhagic focus in the brain. (Alcohol, Berlin-blue reaction.) *a*, Cells containing hæmosiderin; *b*, cells containing hæmatoidin; *c*, fat-granule cells which have become clear; *d*, newly formed connective tissue.  $\times 300$ .

remains of disintegrated red blood-cells which have been taken up by the cells, or from dissolved hæmoglobin which has been absorbed by the cells. In favor of the latter mode of formation is the diffuse yellow color seen in both wandering and fixed cells, which becomes blue when the Berlin-blue reaction is applied. Further, when hæmoglobin is excreted through the kidneys, iron-containing pigment-granules form in the renal epithelium; and moreover fixed cells, as cartilage-cells, for example,

bladder. Gall-stones occur especially in advanced years; stagnation of the bile favors their formation. Inflammations of the mucous membranes of the bile-passages (angiocholitis) lead to desquamation and destruction of the epithelium (eventually also to escape of leucocytes), and in the products derived from these pathological changes bilirubin and cholesterolin are deposited. When once a concretion is formed it increases in size through the deposit of new products of cell-disintegration which become encrusted with cholesterolin, pigment, and calcium. According to Naunyn the originally soft nucleus of the concretion undergoes a change, in that it separates into firm, granular masses of pigment-calcium and crystals of cholesterolin which are deposited upon the outer crust, and into fluid, so that the stones may at times contain a cavity filled with fluid. In the course of time this cavity may again be filled with cholesterolin; and also the pigment and calcium in the remaining portions of the stone



FIG. 99.



FIG. 100.

FIG. 99.—Coral-shaped stone from the bladder, composed of calcium oxalate and phosphate. Natural size.

FIG. 100.—Transverse section of two stones from the bladder, closely fitted together, and consisting of sodium urate and ammonium-magnesium phosphate. Natural size.

may be gradually replaced by cholesterolin. Further, calcium carbonate may also be deposited.

The cholesterolin masses from which the concretions are formed are derived chiefly from the disintegration of epithelial cells; likewise, the lime-salts combining with bilirubin are also furnished by the mucous membrane.

As Elstein has shown, the *urinary calculi, gravel, and stones* are also composed of an organic ground-substance, an albuminous stroma, in which the various constituents of the urine may become deposited. According to location we may distinguish calculi of the kidney and those of the descending urinary passages. In the kidneys the deposits may form only small granules lying in the tissue itself, or in part also free in the lumen of the urinary tubules, in the latter place lying in the products derived from the disintegration of necrotic epithelial cells. This is true in the first place of the calcifications which, as mentioned above, occur in the necrosed renal epithelium after poisoning with corrosive sublimate, bismuth, aloin, copper-salts, iodine, phosphorus, potassium chromate, and oxalic acid. The same thing is true of some of the gouty deposits. Finally, belongs here the so-called *uric-acid infarct of the new-born*, a cou-

dition characterized by the appearance of yellowish-red stripes in the medullary pyramids. The condition is not infrequently seen in children dying during the first five weeks after birth. The epithelium of the tubules is usually well preserved, but in places desquamation and disintegration of single cells may be found. The lumina of the tubules are filled with very small, colorless or yellow granules of urates or uric acid, which at times show fine radiating lines (Fig. 98, *b*). On solution of these granules a delicate stroma remains (*c*). If as the result of the presence of the infarct further changes in the epithelium of the tubules are produced, leading to the formation of albuminous material in the tubules, single granules may under certain conditions develop through accretion into large stones, but this occurrence is rare.

In the pelvis of the kidney, ureters, urinary bladder, urethra, and under the prepuce concretions may be formed, either as sand, gravel, or stones. The last-named are oval or spherical, and may be smooth or rough and nodular, not infrequently resembling a mulberry or mass of coral (Figs. 99 and 100). When several stones lie closely together, their surfaces may become faceted (Fig. 100). Those found in the kidney pelvis may form casts of the cavity and of the calyces.

When examined in section, urinary calculi are sometimes homogeneous, at other times distinctly stratified (Fig. 100) or show radiating lines. Not infrequently there may be seen a nucleus and several zones of different appearances. The crystalline masses lie partly in the spaces of the stroma, and partly in the latter itself; and it may, therefore, be assumed that the stroma is a product of the mucosa of the urinary passages, and that its formation follows catarrhal inflammations or toxic necroses of epithelium when these lead to the collection of mucus or cell-detritus in the tubules.

What substances are deposited in a given case in the products of the mucous membrane depends upon the existing conditions. When the conditions favoring stone-formation are associated with a uric-acid diathesis, or if the excretion of uric-acid salts by causing tissue-necrosis has at the same time produced the conditions favoring the development of concretions, the deposits in the organic ground-substance will consist chiefly of urates. Decomposition of the urine with formation of ammonium-magnesium phosphates leads to the production of calculi consisting chiefly of this substance. Cystin calculi may be formed when cystin is excreted by the kidneys, as the result of peculiar metamorphoses of albumin in the intestine, due to the action of bacteria (Baumann, von Udransky, Brieger). When once a stone is formed, the irritation which it causes upon that portion of the mucous membrane with which it comes in contact, as well as the decomposition of the retained urine, favors its further growth by accretion. Likewise, *foreign bodies* (Fig. 101), which have in any way entered the bladder



FIG. 101.—Incrusted lead-pencil, 12 cm. long, taken from the male urinary bladder. Reduced  $\frac{1}{2}$ .

capillaries of the liver, spleen, lymph-glands, and bone-marrow, and to a less extent in other organs; and are sooner or later taken up by cells.

As the result of an increased supply of hæmoglobin to the liver the functional activity of this organ is increased, so that the *amount of bile-pigment in the bile may be much greater than normal*; and under certain conditions oxyhæmoglobin may appear in the bile (Stern). When the blood-destruction is very great, the liver may not be able to dispose of



FIG. 108.—Hæmochromatosis of the liver. (Alcohol, carmine.) *a*, Acini; *b*, peritoneum; *c*, branches of the portal vein; *d*, infiltrated periportal connective tissue; *e*, pigment lying within the liver-acini; *f*, central veins.  $\times 20$ .

all the blood-pigment brought to it; and in consequence **derivatives of hæmoglobin are deposited**, partly in the liver and partly in other organs, or may be in part **excreted by the kidneys**. In this way there may arise a more or less extensive **hæmochromatosis** of different organs, the cells of which show an ochre-yellow or brown color.

The derivatives of hæmoglobin deposited in this way are partly *iron-free pigments* and partly *hæmosiderin*; but the latter is particularly a frequent cause of pigmentation of tissues, and it is, therefore, proper to speak of a **pigmentation by hæmatogenous siderosis**.

These **deposits of iron-containing pigment** are chiefly in the liver, where they appear partly in the form of yellow granules and lumps, which are for the greater part enclosed in leucocytes lying within the liver-capillaries. Further, they are found also in the form of fine yellow granules, which give the iron-reaction, in the endothelial cells of the capillaries (to which the stellate cells of Kupffer belong), and in the liver-cells (Fig. 107, *a*). In many diseases, as, for example, pernicious malaria or pernicious anæmia, the majority of the liver-cells contain such pigment, so that the liver through the presence of so much iron takes on a characteristic yellowish-brown color.

When large quantities of the products of the disintegration of red



blood-cells are brought to the liver, they accumulate particularly in the periportal connective tissue and in the periphery of the acini (Fig. 108, *d, e*). The lumps or granules of iron-containing pigment lie either free in the capillaries, or in the tissue; or are enclosed within leucocytes, liver-cells, connective-tissue cells, or the capillary endothelial cells. The infiltrated area presents to the naked eye a reddish-brown, rusty color.

The iron-pigment which is carried to the *spleen* is deposited chiefly in the pulp within free cells; but granules are also found in the fixed cells. In the *lymph-glands* the iron granules are found chiefly in the free cells of the lymph-channels. In the *bone-marrow* retained hæmosiderin (Fig. 109) is found partly in free cells lying within the capillaries, and partly in the endothelium, also partly in the marrow-cells; the number of iron containing cells may be very marked.

In the *kidneys* the hæmosiderin granules are most abundant in the epithelium of the convoluted tubules (Fig. 110, *a*), but they are also found in the lumina of the urinary tubules (*b*), in the epithelium of Bowman's capsule (*c*), and in the endothelium of the capillaries. If small particles of hæmosiderin are present in the circulating blood, they will usually be found in the kidney-vessels. When hæmoglobin is excreted by the kidney, drops of this substance will be seen lying in the tubules. In cases of marked deposit of pigment the kidney may show a distinct pigmentation even to the naked eye.

The hæmosiderin, which is found in the different tissues, has been brought to them in the form of small lumps or granules, and is contained chiefly in leucocytes. On the other hand, another part of the iron-gran-

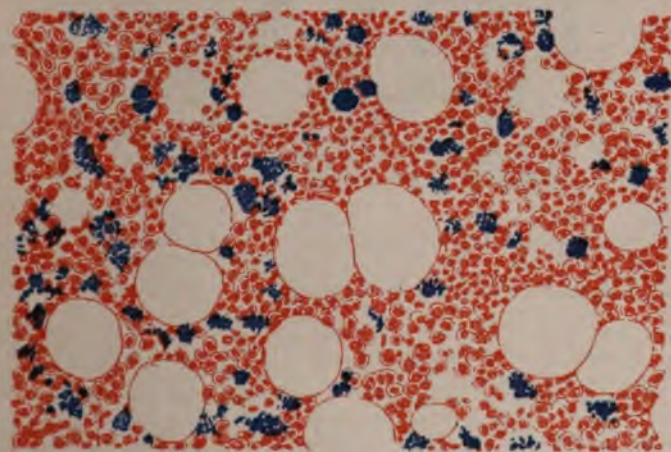


FIG. 109.—Hæmosiderin deposit in the bone-marrow (mixed fatty and lymphoid marrow), in icterus. (Alcohol, carmine, Berlin-blue reaction.)  $\times 300$ .

ules is precipitated in solid form within the cells from substances brought to them in solution. Since the cells (liver-cells, kidney epithelium, endothelium of the blood-vessels, and the cells of the lymph-glands, bone-marrow, and spleen) not infrequently show a diffuse blue color after the iron-test has been applied, the iron must be diffused throughout the cell-protoplasm, and is probably converted later into the granular form. It is also possible that the diffuse coloration may arise in part from a solu-

tion of iron within the cells. According to the observations of different authors it is assumed that besides the colored deposits of pigment, colorless granules of an iron-albuminate may be present in the cells. This theory is supported by the observation that more pigment granules are visible after the iron reaction has been applied, than could be seen before.

The deposit of iron-free pigments, *hæmatoidin* or *bilirubin* is not of frequent occurrence in hæmochromatosis, but occasionally yellow granules which do not give the iron reaction are found in the organs named above; and it may, therefore, be assumed that the pigment in part may be constantly free from iron.

By the majority of authors (see *Geyer, loc. cit.*), the mottled pigmentation of the skin which develops in *chronic arsenic poisoning*, and which is due to the deposit of small yellowish-brown pigment granules in the corium and epidermis (similar to the pigmentation of Addison's disease), is to be classed with the hæmochromatoses. It is to be referred to the degenerative influence of arsenic upon the bone-marrow and the



FIG. 110.—Hæmatogenous deposits of iron in the kidney in pernicious malaria (contracted in Bagamayo). (Alcohol, carmine, Berlin-blue reaction.) *a*, Convoluted tubules, whose epithelial cells contain iron granules and are stained diffusely blue; *b*, iron-granules in the lumen of the tubules; *c*, straight tubules; *d*, glomerulus; *e*, epithelium of the capsule, containing iron-granules.  $\times 150$ .

blood. It should be noted, however, that the pigment does not give the iron reaction, and that, according to other observations, pigment in epithelium which is derived from hæmoglobin is not permanent.

The organism supplies its need for iron through the **assimilation of the iron compounds** found in the iron-containing articles of food. The iron contained in the iron preparations used for medicinal purposes is absorbed from the small intestine, in particular from the duodenum. Iron absorbed in excess is in part stored up as hæmosiderin in the spleen, bone-marrow, and lymph-glands, or temporarily in the liver; and in part excreted through the kidneys, liver, and large intestine.

In *malaria* two pigments are formed as a result of the destruction of the red cells by the malarial parasite. One of these is formed by the malarial plasmodium itself, is contained within the parasite, is black, and gives no iron reaction. Its nature is not known.

The second pigment is hæmosiderin, which passes into the blood-plasma as the result of the destruction of the red blood cells, and is deposited in the liver, spleen, and bone-marrow. In cases of marked destruction of the blood there may occur also a siderosis of the kidneys (Fig. 110), and an excretion of iron in the urine.

The green color which is observed in the neighborhood of blood-containing vessels in decomposing cadavers is to be referred to a formation of sulphur-methæmoglobin through



the action of  $H_2S$  on oxyhæmoglobin (*Hoppe-Seyler, Harnack*). In the absence of oxygen, sulphur-hæmoglobin is formed, which possesses a dark-red color (*Harnack*).

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§ 73. **Icterus** or **jaundice** is a pathological pigmentation of the tissues due to the presence of bile-pigment. Icterus is a symptom which occurs in the course of numerous diseases of the liver, and is of frequent occurrence even in the first days of life (*icterus neonatorum*).

The pathological pigmentation which characterizes icterus is apparent during life, particularly in the skin, conjunctiva, and in the urine; in the cadaver the internal organs—the serous membranes, lungs, kidneys, liver, the subcutaneous and intermuscular tissues, the blood-plasma, clots lying in the vessels, etc.—may show an icteric coloration. In recent cases the icteric color is yellow; in long-standing cases the skin takes on an olive-green or dirty grayish-green color, while similar color-



FIG. 111.—Obstructive icterus of the liver, due to compression of the ductus choledochus by a cancer of the gall-bladder. (Sublimate, alum-carmin.) *a*, Intra-acinous bile-capillaries, moderately dilated and filled with bile; *b*, widely dilated intra-acinous bile-capillary, containing large mass of pigment; *c*, bile-pigment in the liver-cells; *d*, *d*<sub>1</sub>, endothelium stained with bile-pigment; *e*, desquamated endothelium stained with bile-pigment; *f*, pigment mass surrounded by cells; *g*, rupture of the pigment contained in a bile-capillary into a blood-capillary.  $\times 365$ .

ations occur in the internal organs, particularly in the liver, and occasionally in the kidneys.

*Icterus results from the entrance of bile—that is, of bile-pigment (bilirubin)—into the blood and fluids of the body.* During such a condition the urine excreted contains elements of the bile, particularly the bile-pigments.

*Icterus is a hepatogenous disease*, inasmuch as the bile-pigments have their source in the liver. As the result of disease processes in the biliary passages or in the liver itself the normal outflow of the bile is hindered, and the bile is then taken up into the lymphatics and blood-vessels of the liver. Such a damming back of the bile may be caused, for example, by a narrowing or closure of the large bile-ducts through the formation of scar-tissue, through gall-stones wedged in the lumen, or through tumors developing in the bile-ducts themselves, or arising outside of the ducts and compressing them; or through inflammatory processes, abscesses, connective-tissue growths, or tumors of the liver which compress or pull upon, or completely obliterate the smaller bile-ducts, and in this way hinder the outflow of blood from the smaller bile-ducts and capillaries.

When through obstruction of any kind the bile is dammed back into the intrahepatic bile-passages, namely, into the bile-capillaries, there may occur in the first place a resorption of bile through the lymphatics of the liver. As the condition progresses the bile accumulates more and more in the intra-acinous bile-capillaries (Fig. 111, *a*, *b*) and in the liver-cells themselves (*c*), so that finally the masses of bile-pigment (*g*) may break through into the blood-capillaries, the point of rupture often being demonstrable microscopically. Following this the endothelium of the blood-capillaries may also become pigmented (*d*, *d*).

According to recent investigations regarding the structure of the liver, the intracellular bile-capillaries extend into intracellular *secretion-racuoles* (von Kupffer, Pfeiffer) from which are given off extremely fine intracellular secretion-canalculi (Nauwerck, Stroebe, Browicz) surrounding the nucleus as with a meshwork. On the other side the liver-cells stand in the closest relationship to the blood-capillaries. Normally, a double secretion takes place in the liver, an external one of bile-acids and pigment into the bile-passages, and an internal one of sugar and urea (Minkowski) into the blood-vessels. Nauwerck is of the opinion that this latter secretion is also carried through a network of extremely delicate intracellular canaliculi. It is, therefore, easy to understand that disturbances of secretion are of not infrequent occurrence, and that a passage of bile into the blood may be caused, not only through a stasis of the bile, but also through diseased conditions of the liver-cells due to *infections* or *intoxications*. Besides the *icterus due to stasis of the bile*, or *stasis-parapedesis* (Minkowski), there may, therefore, be distinguished an *icterus due to a toxic or infectious parapedesis of the bile* (*paracholia*, Pick). It is probable that many forms of icterus, which were formerly believed to be caused by a catarrhal condition of the bile-passages, are to be interpreted as belonging to the second class.

It is also possible that disturbances of innervation and of the circulation of the liver may be sufficient to bring about an escape of bile into the intra-acinous lymph-channels or into the blood, so that a *nervous paracholia* may also be distinguished.

In *paracholia* of long standing and of a marked severity, as occurs particularly in cases of permanent closure of the bile-passages, not only do the liver-cells become pigmented, but also the endothelium of the blood-vessels (Fig. 111, *d*, *d*). As the result of such pigmentation the cells not infrequently become desquamated (*e*), and lie free in the vessels. Not rarely degenerative changes, cell-necroses, inflammation and proliferation of the connective tissue are also associated with the biliary stasis.



When bile-pigment, either in solution or in the form of granules and lumps, obtains entrance to the blood, the *tissues of the body become gradually permeated with bile-stained lymph*, and thereby acquire an icteric color. If phagocytes containing granules or lumps of bilirubin are present in the circulating blood, they may accumulate here and there, particularly in the spleen and the bone-marrow. After a time the bile-pigment held in solution within the tissue-lymph may become precipitated as *solid particles of bile-pigment*, chiefly in a granular form, but rarely in a crystalline (the latter form occurs almost entirely in the new-born, in which the crystals are found in the fixed and wandering cells of the connective tissue, in the liver-cells, and in the renal epithelium). The crystals are in the form of rhombic plates and needles, similar to those of hæmatoidin (Fig. 104). In severe cases of icterus very many of the tissue-cells contain pigment, and, as a result of the



FIG. 112.—Icterus of the kidney in obstructive jaundice. (Sublimate, carmine.) *a*, Tubular epithelium containing yellowish-brown granules; *b*, large casts stained yellowish-green; *c*, cast containing pigmented cells; *d*, desquamated epithelium containing bile-pigment granules.  $\times 200$ .

metastasis of cells containing pigment, accumulations of the latter in the lymph-glands may occur.

In the kidneys in which bile-pigment is being excreted there likewise occurs an excretory pigmentation, particularly of the epithelium of the urinary tubules (Fig. 112, *a*, *d*), which in consequence may become desquamated. If, as the result of the damage done to the secreting cells through the excretion of the bile-pigment, there are formed, as is usually the case, hyaline casts—that is, hyaline coagula in the albumin-containing urine in the tubules—these likewise become colored by the bile-pigment (Fig. 112, *b*, *c*).

Associated with the deposits of bilirubin in icterus there is always a deposit of hæmosiderin which may become so abundant, particularly in the bone-marrow (Fig. 109), spleen, and lymph-glands, and occasionally also in the liver, that the pigmentation of the organs named is dependent in part upon iron-pigment.

When an *increased destruction of red blood-cells* takes place within the blood-vessels, hæmatoidin or bilirubin, in addition to hæmosiderin, is formed in different parts of the body (see § 72); but the formation of bilirubin outside of the liver is very slight and is not sufficient to cause any extensive icteric coloration of the tissue, so that *a purely hæmatogenous jaundice does not occur*. The liver is the great elaborator of bilirubin, and in cases of increased destruction of the blood-cells the liver-function is increased and there is an increased production and excretion of bile-pigment. An *icterus due to increased destruction of blood-cells* can occur only when at the same time there are present in the liver such changes as cause a *passage of the bile into the blood*.

The question as to whether there is a hæmatogenous as well as a hepatogenous jaundice has long been an object of discussion, and remains unsettled at the present time, in spite of numerous experimental investigations directed toward its solution. Since, as a matter of fact, bilirubin may be formed in the most different kinds of tissue from extravasated blood, the occurrence of a hæmatogenous icterus would *a priori* appear very probable. Experimental investigations as to the results of the destruction of red cells in the circulating blood, particularly through the action of arsenic, toluylendiamin, and potassium chlorate, have shown that the derivatives of blood-pigment which are formed in the tissues and there retained for a long time are essentially iron-containing pigments (hæmosiderin), while the production of bilirubin is practically confined to the liver, which for the time being secretes an increased amount of richly pigmented bile.

According to the investigations of *Minkowski* and *Naunyn*, the urine of geese and ducks after removal of the liver contains no bile-pigment—a fact which would indicate that the transformation of blood-pigment into bile-pigment is ordinarily confined to the liver. The inhalation of arseniureted hydrogen for a few minutes is sufficient to produce in geese in a very short time an intense polycholia and hæmaturia, the urine containing hæmoglobin in solution, disintegrating red cells and biliverdin. If the liver from such a goose be removed, the biliverdin quickly disappears from the urine, and no trace of bile-pigment can be demonstrated in the blood. It is therefore evident that in arsenic poisoning the formation of the bile-pigment is confined to the liver, in which organ leucocytes enclosing iron-containing fragments of broken-down red cells are found to be present.

In so far as it is possible to judge from the experimental investigations which have been made up to the present time, a pure hæmatogenous jaundice does not appear to occur. The mere fact of the occurrence of jaundice after intoxications, inhalation of ether and chloroform, transfusion of blood, snake-bite, septicæmia, typhoid fever, yellow fever, paroxysmal hæmoglobinuria, etc., cannot be taken as proof of the existence of a hæmatogenous jaundice. There is, indeed, in these conditions an increased destruction of red blood-cells; but bilirubin is essentially a product of the liver, and if jaundice occurs it can be due only to the fact that a portion of the bile-pigment, which is produced in excess, has found its way into the blood. It appears that a change in the consistency of the bile is sufficient (*Stadelmann*) to cause an absorption of bile-pigment into the blood.

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§ 74. **Pigmentation of the tissues through substances introduced into the body from without** occurs when substances possessing a color of their own gain entrance in some manner to the tissues, where they are able to remain for some time without suffering changes. The number of such substances is large, and the manner of entrance varied. The most common avenues of entrance are the *lungs, wounds, and intestinal tract*. The



FIG. 113.—Deposit of cinnabar in tattooed skin. (Alcohol, alum carmine.) *a*, Epithelium; *b*, corium; *c*, cinnabar.  $\times 80$ .

most familiar pigmentation through wounds is *tattooing of the skin*, which is frequently practised by individuals of civilized as well as of uncivilized nations.

The method of tattooing colored figures, etc., consists in the introduction of insoluble granular pigments, such as carbon, cinnabar, etc., into slight wounds of the skin. The pigments are rubbed into the

wounds, whence they penetrate and infiltrate the tissue in their immediate neighborhood. A portion of the pigment remains in the *corium* (Fig. 113, *c*); another portion is carried to the lymph-glands, which thereby become pigmented.

The lungs and their lymph-glands may become intensely pigmented through the inhalation of *colored dust*, such as coal-dust, soot, iron-dust, etc. Through the inhalation of coal-dust the lungs may become wholly black.

When coal-dust is taken into the lungs in the respired air a portion of the pigment is carried to the peribronchial lymph-glands, which in consequence may become black. When the deposit is very abundant the lymph-glands may undergo softening.

If the glands are situated in the neighborhood of a vein, the pigment-deposit and the softening may involve the vein-wall, so that finally particles of coal-dust may pass into the blood-stream, and be carried to other organs, the spleen, liver, and bone-marrow (see § 21).

From the *intestine* only soluble substances are absorbed, and a permanent pigmentation can therefore occur, only when these are precipitated in the tissue in a solid form, which is at the same time either black or possessing some color. The most frequent of such pigmentations is that known as *argyria*, which is due to the long-continued use of silver-preparations. In this condition the skin may show an intense grayish-brown discoloration, and the internal organs may also present more or less pigmentation. The silver is deposited in the ground-substance of the tissues in the form of fine granules, more especially in the glomeruli, and the connective tissue of the medullary pyramids (Fig. 114, *b*), the intima of the great vessels, adventitia of the smaller ones, in the neighborhood of the mucous glands, the papillæ of the skin, connective tissue of the intestinal villi, and in the choroid plexus of the lateral ventricles. Deposits may occur also in the serous membranes, but the epithelial tissues, the brain, and the cerebral vessels escape. Extensive deposits of silver pigment in the medullary portion of the kidneys may lead to the formation of hyaline connective tissue, which may undergo calcification.

Under especial conditions *iron*, when taken into the body in excessive amounts, may be deposited in the bone-marrow, spleen, and lymph-glands; but the pigmentation thus produced is only rarely visible to the naked eye. In *lead-poisoning* there may be seen a grayish-black discoloration of the gums, which is due to the deposit of granules of sulphide of lead in the connective tissue of the mucous membrane. They are pro-

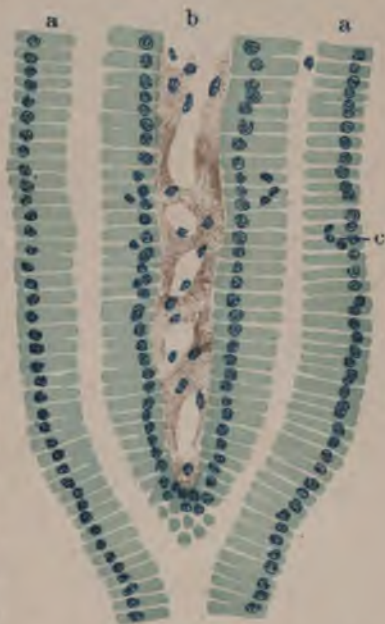


FIG. 114.—Deposits of silver in the pyramidal portion of a rabbit's kidney, after seven months' administration of silver salts (experiment by von Kahliden.) (Alcohol, hæmatoxylin.) *a*, Epithelium of the collecting tubes; *b*, connective tissue with brown silver granules.  $\times 500$ .

duced through the action of hydrogen sulphide upon the lead, which is present in solution in the mucous membrane.

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### XV. The Pathological Absence of Pigment.

§ 75. The **absence of pigment** occurs, in the first place, as a congenital condition, and is then termed **albinism** or **leucopathia congenita**.



FIG. 115. —Vitiligo endemica (after a photograph received from Professor Münch.)

In a part of such cases the absence of pigment extends over the entire body (*albinismus universalis*, *Kakerlaken*, *albinos*); in other cases it is restricted to certain portions of the skin (*albinismus partialis*). In those parts of the skin which are destitute of pigment the hairs likewise may contain no pigment, and appear white or yellowish-white (*poliosis* or *leucotrichia congenita universalis*, or *circumscripta*). In universal albinism the pigment of the retina, choroid, and iris may also be wanting, so that consequently the choroid, from the amount of blood which it contains, appears red, and the iris, according to the angle of observation and the degree of illumination, will appear either bluish-white or red. On microscopical examination no pigmented cells can be found.

A second form of absence of pigment is that condition which is known as **vitiligo** or **leucopathia acquisita**. This occurs later in life, either as a sequela to certain well-known diseases (scarlet fever, typhus, recurrent fever), or as a symptom of an epidemic disease of unknown etiology (*vitiligo endemica*), or finally without any recognizable cause. The formation of white spots, within which the hairs are also white (*leucotrichia acquisita circumscripta*), takes place usually symmetrically, and may extend over the greater part of the body (Fig. 115). The white

areas are surrounded by a border of more deeply pigmented skin; and this suggests that with the disappearance of the pigment at one point the pigment is transferred to adjacent parts. The loss of color in the hairs (even as in old age) begins always in the root, no more pigment being transferred from the hair-papilla to the hair-bulb. Finally the pigment-cells of the papilla disappear altogether.

A third form of loss of pigment is associated with traumatic or infectious *inflammations* of the skin, particularly in syphilitic exanthemata and in leprosy; this condition is known as **leucoderma**.

In scars of the skin which remain white, the newly formed tissue replacing the defect does not possess the power of producing pigment; and consequently represents a colorless cicatrix covered by epithelium. Not infrequently such a scar may be surrounded by a pigmented border. In mild forms of inflammation, in which the tissue of the skin suffers no loss (syphilis), the disappearance of color may immediately follow the inflammation, or not until later, in which case there may occasionally occur a preceding stage of increased pigmentation. According to Ehrmann the lack of pigment in such cases is to be explained either by the fact that no chromatophores are present in the corium to furnish pigment to the epithelium, or the changed epithelium is not able to take up the pigment from the latter when present. The pigment which still remains in the cutis may then be absorbed.

According to Münch, vitiligo is of common occurrence in Turkestan, and is considered by the natives (Sarts) to be contagious, so that they isolate the individuals affected with this disease and confine them with lepers in enclosed courts. It is probable that in the literature vitiligo endemica has been many times mistaken for lepra maculosa, and has been described under the designation "white leprosy of the Jews."

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### XVI. The Formation of Cysts.

§ 76. A **cyst** is a circumscribed cavity which is shut off from the surrounding tissues by a connective-tissue membrane or by tissue of a more complex structure, and possessing contents differing in nature from the capsule. Cysts may occur in any tissue. When composed of but a single chamber, the cyst is called a *simple cyst*; when divided into a number of compartments, it is known as a *multilocular cyst*.

The most common form is the so-called **retention-cyst**, which arises from the accumulation of secretions in preëxisting spaces which are lined with epithelium or endothelium.

In glands provided with an open duct, retention-cysts will be formed as the result of the obstruction of the duct, provided that actively-

secreting epithelium still exists behind the point of obstruction. Such cysts are of frequent occurrence in the sebaceous glands, hair-follicles,

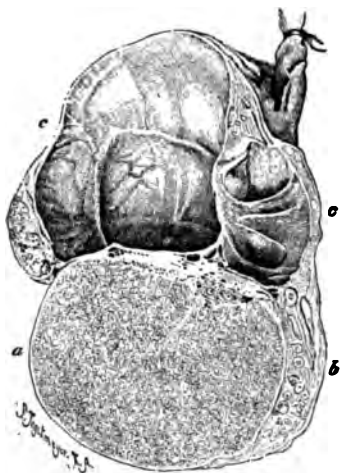


FIG. 116.—Section of the testicle and epididymis, with multiple cysts in the head of the epididymis. *a*, Testis; *b*, epididymis; *c*, multilocular cysts. Slightly reduced.

uterine glands, mucous glands of the intestinal tract, tubules of the epididymis (Fig. 116, *c*), urinary tubules (Fig. 74); less frequent in the biliary passages, in the breast, pancreas (Fig. 117, *b*), in the glands of the mouth, etc. **Larger open canals**, such as the ureters, vermiform appendix, and tubes (Fig. 118, *c*), may also undergo cystic dilatation as the result of the collection of secretions. The obstruction of a given duct may be due to accumulation of secretion, to the formation of adhesions (Fig. 118, *e*), cicatricial obliteration, compression, or constriction of its lumen.

**Closed glandular cavities and tubes**, such as the follicles of the thyroid and the glandular tubes of the parovarium, may also become cystic when their walls produce an abnormal amount of secretion. Likewise, the **remains of fetal passages and clefts**, as, for example, urachus, Müller's ducts, etc., may also become cystic.

Small cysts, such as those developing in mucous glands, vary in size from a millet seed to that of a pea. Larger cysts, such as occur in the liver and ovaries, may attain the size of a fist and even larger.

The **contents of cysts** depend upon the nature of the tissue in which they are formed. Thus the cysts of the sebaceous glands and hair-follicles (*atheroma*) contain a pultaceous, white, or grayish-white, more rarely brown, mass, which consists essentially of squamous cells, in part showing cornification, and also of fat-globules and cholesterolin. The cysts occurring in mucous glands contain a mucous fluid which is either clear, or white and cloudy, as the result of the presence of cellular elements.

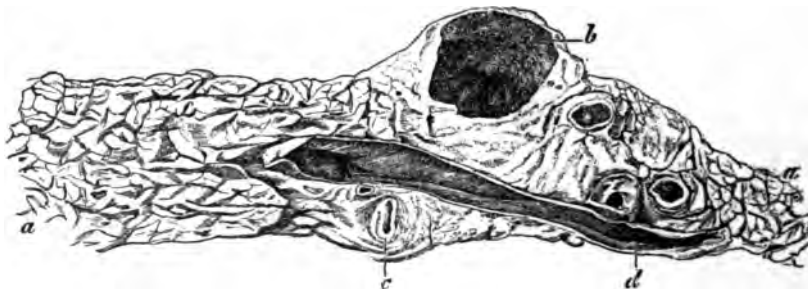


FIG. 117.—Pancreas cyst, due to dilatation of branches of Wirsung's duct. *a*, Gland-tissue; *b*, cysts; *c*, transverse section of artery; *d*, longitudinal section of vein. Natural size.

Hæmorrhage into a cyst from the cyst-wall gives a red or brown color to the contents. When great numbers of cells are present in the cyst-contents, this may become converted into a semi-solid fatty mass, which



may undergo calcification. Cysts of the thyroid and kidneys contain colloid masses, or a clear though occasionally cloudy fluid.

**Retention-cysts lined with endothelium** may develop from blood- and lymph-vessels, lymph-spaces, bursæ, and tendon-sheaths. Here also the content of the cyst is dependent upon its place and mode of origin.

As retention-cysts increase in size the stretching of the cyst-wall would ultimately lead to a defect in the continuity of the wall if no *new formation of tissue* took place. Cyst formation is, therefore, not purely a degenerative process; such a new formation of tissue takes place first in the epithelial or endothelial lining of the cyst, but the connective-tissue elements of the wall also increase, so that in spite of the stretching

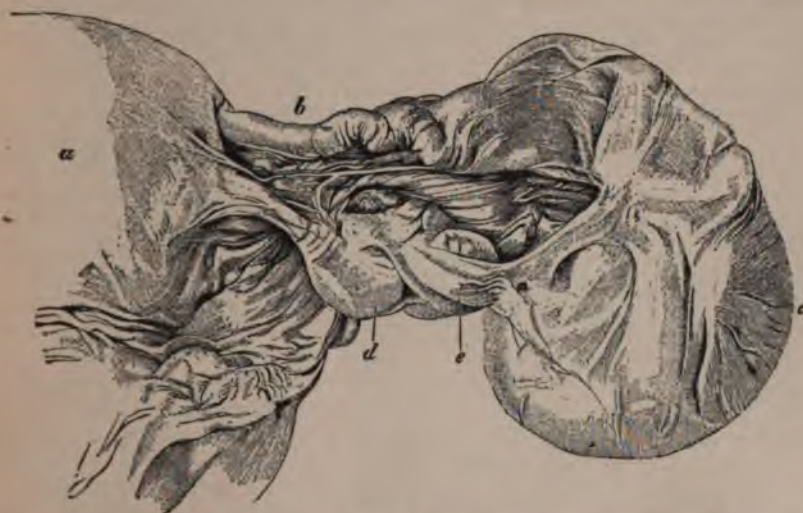


FIG. 118.—Hydrops of the Fallopian tube, with perisalpingitic and periovarian adhesions. a, Uterus; b, uterine portion of the tube showing cystic dilatation and adhesions with the neighboring parts; d, ovary; c, membranous adhesion. Two-thirds natural size.

the wall of the cyst becomes no thinner, and under certain conditions may even increase in thickness. Moreover, **cyst formation is often associated with a pathological formation of new glandular tissue**, and in this way constitutes a secondary change in hypertrophic or tumor-like growths. It is, therefore, sometimes impossible to draw a sharp line between the simple cystic dilatations of preëxisting gland-canals and gland-spaces, and those tumors, the **cystomata**, which are characterized by cyst formation (see Cystoma). *Endothelial cysts may also develop out of newly formed lymph-spaces and lymph-vessels.*

A second form of cyst is the **degeneration-cyst**, which arises through the partial disintegration and liquefaction of a tissue. Cysts formed in this manner occur in the brain, hypertrophic thyroids, and in tumors. They may contain a clear or cloudy, or at times hæmorrhagic exudate.

A third form of cysts results from the formation of a **connective-tissue capsule** around **foreign bodies**, which have found entrance to the tissues, as, for example, about a bullet; or also about **necrotic areas**, or **hæmorrhagic extravasates**.

A fourth variety of cysts is formed by **parasites** which pass through

a cystic stage in the course of their development in the body, and are likewise surrounded by a *connective-tissue capsule*.

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## CHAPTER VI.

### Hypertrophy and Regeneration. Results of Tissue-Transplantation. Metaplasia.

#### I. General Considerations Concerning the Processes Known as Hypertrophy and Regeneration, and the Accompanying Cellular Changes.

§ 77. In a general sense, **hypertrophy** is an *increase in the size of a tissue or organ, due either to an increase in the size or in the number of the individual elements*, in such a way that the structure of the hypertrophic tissue is like that of the normal, or at least does not differ essentially from it.

In a more limited sense *hypertrophy is an increase in size due to an enlargement of the individual elements alone; the enlargement due to an increase in the number of the individual elements being designated as hyperplasia.*

Hypertrophy may result from morbid impulses inherent in the germinal cells, or from influences acting during the life of the individual.

If an abnormal tissue-increase occurs during the period of embryonal development, or of extra-uterine growth, and if no influences are recognizable that would account for the increased growth, the condition may be explained as the result of a **congenital predisposition**, and may be designated as a **hypertrophy due to a congenital anlage**. If the enlargement affects the entire body, for example, if a newly born child weighs 5-6 kgm., or if an individual should reach the height of 180-200 cm., the condition is called a **general giant growth**. When the enlargement affects only individual parts of the body, as, for example, the entire head or one-half of it, or one extremity, or a finger, or the vulva, it is called a **partial giant growth**. The giant growth of several parts of one side of the body is designated a *half giant growth*; one involving



FIG. 119.—Elephantiasis femorum neuromatosa.

all the body-parts is very rare. Hypertrophic growths of the skin and subcutaneous tissues, leading to a disfigurement suggesting the appearance of the skin of the pachydermata, are known as **elephantiasis** (Figs. 119, 120).



FIG. 120.—Elephantiasis cruris lymphangiectatica.

In hypertrophic growth of an extremity or of a finger all the elements of the same are uniformly enlarged. In elephantiasis of the extremities the connective tissue of the skin and subcutaneous structures is especially likely to become increased; but the development and structure of these growths vary greatly. In one case all the connective-tissue elements may be uniformly increased, in another case only individual elements; as, for example, the connective tissue of the nerves, blood- or lymph-vessels; or at least, the pathological new-formation takes its start from these. It is therefore possible to distinguish *different forms of elephantiasis* according to the structure of the hypertrophic part: *elephantiasis neuro-matosa* (Fig. 119), *angiomatosa*, *lymphangiectatica* (Fig. 120), *lipomatosa*, *fibrosa*, etc.

If, as a result of some peculiar predisposition of the skin, there occurs a hypertrophy of the horny layer of the epidermis (Fig. 121, *e*), so that the skin becomes covered with horny plates, scales, or even with spines, the condition is designated **ichthyosis**.



FIG. 121.—Ichthyosis congenita. Section through the skin of the trunk of the body (alcohol, picrocarmine.) *a*, Corium, with glands; *b*, papillary body, with rete Malpighii; *c*, hypertrophic horny layer of the epidermis; *d*, dilated hair-follicles, lined with horny epithelium; *e*, hairs.  $\times 40$ .

This change may be present even at birth (*ichthyosis congenita*); and the new-born child (Fig. 122) may be wholly covered with hard horny plates, which have been split open at different points as the result of the growth of the underlying tissues. The pathological cornification affects chiefly the surface (Fig. 121, c), but may extend also into the hair-follicles (Fig. 121, d).

In other cases, at a later period of development, as during the first years of life, localized thickenings of the horny layer may develop, consisting of either small scales or plates, or larger ones, giving the skin a rough and checkered appearance. The corium and the papillæ are usually not involved in the ichthyosis; but occasionally the papillary bodies may be hypertrophic and enlarged, thus increasing the rough and nodular appearance of the surface (*ichthyosis hystrix*). When the excessive cornification is sharply limited to areas of small size, there are formed circumscribed warts with rough, epithelial covering, which are known as *ichthyotic warts*. In rare cases there may be developed a more extensive horny layer over the hypertrophic papillæ, whose scales are arranged at right angles to the surface of the skin; and these occasionally may attain to such size that they are called **cutaneous horns** (Figs. 123, 124).



FIG. 122.—*Ichthyosis congenita*.



FIG. 123.—*Cornu cutaneum*, from back of hand. (Natural size.)



FIG. 124.—*Cornu cutaneum*, from arm. (Natural size.)

The hypertrophic development of hair over those parts of the body where only downy hair, or even no hair at all, should be found is known as **hypertrichosis**. Such an abnormal hairiness may cover a larger or smaller area of the body, and depends either upon a persistence and abnormal development of the lanugo (*hypertrichosis lanuginosa fœtalis*) (Fig. 125), or upon a pathological development of the secondary hairs. An excessive growth of the nails leads to the condition known as *hyperonychchia*, which is often followed by a claw-like deformity of the same designated *onychogryphosis*. It is to be noted, however, that the pathological over-growths of the nails are usually acquired.



Next to the enlargements associated with general or partial giantism the **bones** most frequently undergo a form of hypertrophy corresponding to the congenital elephantiasis of the skin. The head is usually affected, the bones of which may undergo a very marked enlargement (Fig. 126), leading to a deformity in which the patient's head comes to resemble that of a lion, hence the name **leontiasis ossea**. Further, there often develop upon the skull or other bones of the body circumscribed bony growths known as **exostoses**, which are inherited and not dependent upon extrinsic influences.

In the **internal organs** hypertrophic processes dependent purely upon intrinsic causes are rare; but the brain, for example, may reach an abnormal size.

It cannot always be definitely stated to what extent hypertrophy of the tissues is to be attributed to a congenital predisposition, inasmuch as many extrinsic influences are able to produce proliferations of tissue similar to those due to



FIG. 125.—Head of a hairy individual, a woman. (After Hebra.)



FIG. 126.—Leontiasis ossea, occurring in a boy affected with general giant-growth. (Observed by von Buhl.)

intrinsic causes. For example, cutaneous horns and elephantiasis-like thickenings of the skin may develop as the result of inflammation.

In general, the early appearance of a hypertrophic growth, the hereditary nature of the pathological peculiarity, and the absence of an external etiological factor, speak for the congenital nature of the condition. The fact that later influences may apparently cause the growth does not preclude the existence of a congenital predisposition. Thus the excessive bony growths of the head above mentioned may follow trauma or acute inflammations. External influences may therefore be the exciting cause of the proliferation, but not the primary cause of the same; since we know by experience that the given injurious influences are able to produce such changes only in tissues possessing a special predisposition.

Not infrequently an abnormal tendency to excessive growth may show

itself in a *premature development of certain organs, the structure remaining normal*. The external and internal sexual organs are most frequently affected. Girls, even in the first years of life, may show a development of breasts and external genitals and a growth of hair corresponding to that of the sexually ripe woman; and menstruation may be established at this early period.

The size of the entire body as well as of its separate parts and organs shows considerable variation within physiological limits, according to the race, family, and individual. The variation in the relation of the size of single parts and organs to that of the entire body is less marked.

The average height of the body in well-built individuals is, according to Vierordt ("Daten u. Tabellen für Med.," Jena, 1893), as follows: Men 172 cm., women 160 cm.; of the new-born, males 47.4 cm., females 46.75 cm. The average body-weight in Europe is for men about 65 kgm., that of women about 55 kgm., that of the new-born about 3,250 gm.

The average weight of the internal organs is as follows, the figures in parentheses being for the new-born: Brain 1,397 (385) gm., heart 304 (24) gm., lungs 1,172 (58) gm., liver 1,612 (118) gm., spleen 201 (11.1) gm., right kidney 131, left kidney 150 gm., both kidneys 299 (23.6) gm., testicles 48 (0.8) gm., muscles 29,880 (625) gm., skeleton 11,560 (445) gm. Expressed in percentages of the body-weight the figures for adults and new-born are (the latter in parentheses): Heart 0.52 (0.89), kidneys 0.48 (0.88), lungs 2.01 (2.16), stomach and intestines 2.34 (2.53), spleen 0.346 (0.41), liver 2.77 (4.80), brain 2.37 (14.34), adrenals 0.014 (0.31), thymus 0.0086 (0.54), skeleton 15.35 (16.17), muscles 43.09 (33.4).

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§ 78. The **hypertrophies of the tissues due wholly to extrinsic influences without the aid of a congenital predisposition** owe their origin either to an increase in the activity of the tissue, to diminished use, defective retrograde change, or finally to prolonged or frequently repeated mechanical, chemical, and infectious irritations of the tissues. Under certain conditions the removal of pressure may also give rise to a localized hypertrophy.

**Hypertrophy from overwork** is most frequently observed in the case of *muscles* and *glands*, but may occur also in other tissues. If the *heart* is called upon to do an extra amount of work as the result of diseased con-



FIG. 127.—Transverse section of a heart showing hypertrophy of the left ventricle, resulting from aortic stenosis and insufficiency. *a*, Left, *b*, the right ventricle. Reduced  $\frac{1}{16}$ .

ditions of the valves, aorta, or kidneys, and if such conditions exist for some time, that part of the heart-muscle upon which the extra work falls suffers a more or less pronounced hypertrophy (Fig. 127), so that as a result the mass of the heart may reach double that of the normal or even more.

In a similar manner the *striated muscles*, and the *unstriated muscle of the bladder, ureters, uterus, intestine, and blood-vessels* may become hypertrophic as the result of persistent increase in their activity.

As the result of an increase of the supporting strain from whatever cause the *bones* may become thickened, and the bony trabeculae of the medullary portion become increased in size.

Of the *glands*, the *kidneys*, and *liver* in particular are able to change their size according to the functional demands, and may consequently present a marked hypertrophy. Should one kidney be destroyed the remaining one may become so enlarged that it may reach approximately



the same weight that the two kidneys together originally possessed. Likewise the liver after a destruction of a part of its parenchyma through disease may make good its loss by a hypertrophy of the remaining tissue. Since in this way a compensation for the defect and a



FIG. 128.—Hypertrophy of an incisor tooth of a white rat, the result of an oblique position of the jaw. (Natural size.)

restoration of the normal function is brought about, such a tissue-increase may be appropriately designated **compensatory hypertrophy**. The same term may also be applied to muscle-hypertrophy, if through its functional disturbances are compensated. A similar compensatory hypertrophy is said to occur also in the case of adrenal tissue. In the case of other glands, such as the salivary glands, ovaries, testicles, and mammary glands, such a compensatory hyper-

trophy either does not occur at all, or takes place only during the period of development. The loss of an ovary or testis in adult life can hardly result in an increased activity or hypertrophy of the remaining organ. Extirpation of the larger part of the thyroid gland is not followed by any pronounced hypertrophy of the remaining portion; but, on the other hand, the hypophysis undergoes an enlargement which must be regarded as compensatory. In the case of the *lungs*, an increase in the activity of one portion after the loss of other parts results usually in a permanent overdistention which may lead eventually to atrophy. On the other hand, if during embryonic life a defective development of one lung takes place, the other lung may undergo a compensatory growth, which in the case of total agenesis of one lung may reach a very pronounced degree. For the other organs the general principle may be applied that compensatory hypertrophy is the more perfect the younger the individual. In the case of the brain a compensatory growth of one part after the loss of another is possible only during the early stages of development.

**Hypertrophy from lessened use** occurs in the case of tissues which are subjected to a constant use. Thus, for example, a diminished desquamation of the horny layer of the epidermis leads to its pathological thickening. If, as the result of the destruction of an opposing tooth or an oblique position of the teeth, the incisor teeth in rodents are not worn down by use, they may grow out into long and curved tusks (Fig. 128). Likewise the finger- and toe-nails may reach an abnormal size either from lack of wear or from being left uncut. **Hypertrophy due to defective retrograde change** occurs in organs which after a definite,



FIG. 129.—Elephantiasis scroti in a Samoan nineteen years of age. (After Uthemann, *Deutsche med. Wochenschr.*, 1895.)

period of physiological growth undergo a diminution in size. For ex-



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FIG. 116.—Section of the testicle and epididymis, with multiple cysts in the head of the epididymis. *a*, Testis; *b*, epididymis; *c*, multilocular cysts. Slightly reduced.

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FIG. 118.—Hydrops of the Fallopian tube, with perisalpingitic and periovarian adhesions. *a*, Uterus; *b*, uterine portion of the tube showing cystic dilatation and adhesions with the neighboring parts; *d*, ovary; *c*, membranous adhesion. Two-thirds natural size.

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## CHAPTER VI.

### Hypertrophy and Regeneration. Results of Tissue-Transplantation. Metaplasia.

#### I. General Considerations Concerning the Processes Known as Hypertrophy and Regeneration, and the Accompanying Cellular Changes.

§ 77. In a general sense, **hypertrophy** is an *increase in the size of a tissue or organ, due either to an increase in the size or in the number of the individual elements*, in such a way that the structure of the hypertrophic tissue is like that of the normal, or at least does not differ essentially from it.

In a more limited sense *hypertrophy is an increase in size due to an enlargement of the individual elements alone; the enlargement due to an increase in the number of the individual elements being designated as hyperplasia.*

Hypertrophy may result from morbid impulses inherent in the germinal cells, or from influences acting during the life of the individual.

If an abnormal tissue-increase occurs during the period of embryonal development, or of extra-uterine growth, and if no influences are recognizable that would account for the increased growth, the condition may be explained as the result of a **congenital predisposition**, and may be designated as a **hypertrophy due to a congenital anlage**. If the enlargement affects the entire body, for example, if a newly born child weighs 5-6 kgm., or if an individual should reach the height of 180-200 cm., the condition is called a **general giant growth**. When the enlargement affects only individual parts of the body, as, for example, the entire head or one-half of it, or one extremity, or a finger, or the vulva, it is called a **partial giant growth**. The giant growth of several parts of one side of the body is designated a *half giant growth*; one involving



FIG. 119.—Elephantiasis femorum neuromatosa.

all the body-parts is very rare. Hypertrophic growths of the skin and subcutaneous tissues, leading to a disfigurement suggesting the appearance of the skin of the pachydermata, are known as **elephantiasis** (Figs. 119, 120).



FIG. 120.—Elephantiasis cruris lymphangectatica.

In hypertrophic growth of an extremity or of a finger all the elements of the same are uniformly enlarged. In elephantiasis of the extremities the connective tissue of the skin and subcutaneous structures is especially likely to become increased; but the development and structure of these growths vary greatly. In one case all the connective-tissue elements may be uniformly increased, in another case only individual elements; as, for example, the connective tissue of the nerves, blood- or lymph-vessels; or at least, the pathological new-formation takes its start from these. It is therefore possible to distinguish *different forms of elephantiasis* according to the structure of the hypertrophic part: *elephantiasis neuro-matosa* (Fig. 119), *angiomatosa*, *lymphangiectatica* (Fig. 120), *lipomatosa*, *fibrosa*, etc.

If, as a result of some peculiar predisposition of the skin, there occurs a hypertrophy of the horny layer of the epidermis (Fig. 121, c), so that the skin becomes covered with horny plates, scales, or even with spines, the condition is designated **ichthyosis**.



FIG. 121.—Ichthyosis congenita. Section through the skin of the trunk of the body (alcohol, picrocarmine.) a, Corium, with glands; b, papillary body, with rete Malpighii; c, hypertrophic horny layer of the epidermis; d, dilated hair-follicles, lined with horny epithelium; e, hairs.  $\times 40$ .



This change may be present even at birth (*ichthyosis congenita*); and the new-born child (Fig. 122) may be wholly covered with hard horny plates, which have been split open at different points as the result of the growth of the underlying tissues. The pathological cornification affects chiefly the surface (Fig. 121, *c*), but may extend also into the hair-follicles (Fig. 121, *d*).

In other cases, at a later period of development, as during the first years of life, localized thickenings of the horny layer may develop, consisting of either small scales or plates, or larger ones, giving the skin a rough and checkered appearance. The corium and the papillæ are usually not involved in the ichthyosis; but occasionally the papillary bodies may be hypertrophic and enlarged, thus increasing the rough and nodular appearance of the surface (*ichthyosis hystrix*). When the excessive cornification is sharply limited to areas of small size, there are formed circumscribed warts with rough, epithelial covering, which are known as *ichthyotic warts*. In rare cases there may be developed a more extensive horny layer over the hypertrophic papillæ, whose scales are arranged at right angles to the surface of the skin; and these occasionally may attain to such size that they are called **cutaneous horns** (Figs. 123, 124).

The hypertrophic development of hair over those parts of the body where only downy hair, or even no hair at all, should be found is known as **hypertrichosis**. Such an abnormal hairiness may cover a larger or



FIG. 122.—Ichthyosis congenita.



FIG. 123.—Cornu cutaneum, from back of hand. (Natural size.)



FIG. 124.—Cornu cutaneum, from arm. (Natural size.)

smaller area of the body, and depends either upon a persistence and abnormal development of the lanugo (*hypertrichosis lanuginosa foetalis*) (Fig. 125), or upon a pathological development of the secondary hairs. An excessive growth of the nails leads to the condition known as *hyperonychia*, which is often followed by a claw-like deformity of the same designated *onychogryphosis*. It is to be noted, however, that the pathological over-growths of the nails are usually acquired.



Next to the enlargements associated with general or partial giantism the **bones** most frequently undergo a form of hypertrophy corresponding to the congenital elephantiasis of the skin. The head is usually affected, the bones of which may undergo a very marked enlargement (Fig. 126), leading to a deformity in which the patient's head comes to resemble that of a lion, hence the name **leontiasis ossea**. Further, there often develop upon the skull or other bones of the body circumscribed bony growths known as **exostoses**, which are inherited and not dependent upon extrinsic influences.

In the **internal organs** hypertrophic processes dependent purely upon intrinsic causes are rare; but the brain, for example, may reach an abnormal size.

It cannot always be definitely stated to what extent hypertrophy of the tissues is to be attributed to a congenital predisposition, inasmuch as many extrinsic influences are able to produce proliferations of tissue similar to those due to



FIG. 125.—Head of a hairy individual, a woman. (After Hebra.)



FIG. 126.—Leontiasis ossea, occurring in a boy affected with general giant-growth. (Observed by von Buhl.)

intrinsic causes. For example, cutaneous horns and elephantiasis-like thickenings of the skin may develop as the result of inflammation.

In general, the early appearance of a hypertrophic growth, the hereditary nature of the pathological peculiarity, and the absence of any external etiological factor, speak for the congenital nature of the condition. The fact that later influences may apparently cause the growth does not preclude the existence of a congenital predisposition. Thus the excessive bony growths of the head above mentioned may follow trauma or acute inflammations. External influences may therefore be the exciting cause of the proliferation, but not the primary cause of the same; since we know by experience that the given injurious influences are able to produce such changes only in tissues possessing a special predisposition.

Not infrequently an abnormal tendency to excessive growth may show

itself in a *premature development of certain organs, the structure remaining normal*. The external and internal sexual organs are most frequently affected. Girls, even in the first years of life, may show a development of breasts and external genitals and a growth of hair corresponding to that of the sexually ripe woman; and menstruation may be established at this early period.

The size of the entire body as well as of its separate parts and organs shows considerable variation within physiological limits, according to the race, family, and individual. The variation in the relation of the size of single parts and organs to that of the entire body is less marked.

The average height of the body in well-built individuals is, according to Vierordt ("Daten u. Tabellen für Med.," Jena, 1893), as follows: Men 172 cm., women 160 cm.; of the new-born, males 47.4 cm., females 46.75 cm. The average body-weight in Europe is for men about 65 kgm., that of women about 55 kgm., that of the new-born about 3,250 gm.

The average weight of the internal organs is as follows, the figures in parentheses being for the new-born: Brain 1,397 (385) gm., heart 804 (24) gm., lungs 1,172 (58) gm., liver 1,612 (118) gm., spleen 201 (11.1) gm., right kidney 131, left kidney 150 gm., both kidneys 299 (23.6) gm., testicles 48 (0.8) gm., muscles 29,880 (625) gm., skeleton 11,560 (445) gm. Expressed in percentages of the body-weight the figures for adults and new-born are (the latter in parentheses): Heart 0.52 (0.89), kidneys 0.48 (0.88), lungs 2.01 (3.16), stomach and intestines 2.34 (2.53), spleen 0.346 (0.41), liver 2.77 (4.80), brain 2.37 (14.34), adrenals 0.014 (0.31), thymus 0.0086 (0.54), skeleton 15.35 (16.17), muscles 43.09 (33.4).

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§ 78. The **hypertrophies of the tissues due wholly to extrinsic influences without the aid of a congenital predisposition** owe their origin either to an increase in the activity of the tissue, to diminished use, defective retrograde change, or finally to prolonged or frequently repeated mechanical, chemical, and infectious irritations of the tissues. Under certain conditions the removal of pressure may also give rise to a localized hypertrophy.

**Hypertrophy from overwork** is most frequently observed in the case of *muscles* and *glands*, but may occur also in other tissues. If the *heart* is called upon to do an extra amount of work as the result of diseased con-



FIG. 127.—Transverse section of a heart showing hypertrophy of the left ventricle, resulting from aortic stenosis and insufficiency. *a*, Left, *b*, the right ventricle. Reduced  $\frac{1}{10}$ .

ditions of the valves, aorta, or kidneys, and if such conditions exist for some time, that part of the heart-muscle upon which the extra work falls suffers a more or less pronounced hypertrophy (Fig. 127), so that as a result the mass of the heart may reach double that of the normal or even more.

In a similar manner the *striated muscles*, and the *unstriated muscle of the bladder, ureters, uterus, intestine, and blood-vessels* may become hypertrophic as the result of persistent increase in their activity.

As the result of an increase of the supporting strain from whatever cause the *bones* may become thickened, and the bony trabeculae of the medullary portion become increased in size.

Of the *glands*, the *kidneys*, and *liver* in particular are able to change their size according to the functional demands, and may consequently present a marked hypertrophy. Should one kidney be destroyed the remaining one may become so enlarged that it may reach approximately



the same weight that the two kidneys together originally possessed. Likewise the liver after a destruction of a part of its parenchyma through disease may make good its loss by a hypertrophy of the remaining tissue. Since in this way a compensation for the defect and a



FIG. 128.—Hypertrophy of an incisor tooth of a white rat, the result of an oblique position of the jaw. (Natural size.)

restoration of the normal function is brought about, such a tissue-increase may be appropriately designated **compensatory hypertrophy**. The same term may also be applied to muscle-hypertrophy, if through it functional disturbances are compensated. A similar compensatory hypertrophy is said to occur also in the case of adrenal tissue. In the case of other glands, such as the salivary glands, ovaries, testicles, and mammary glands, such a compensatory hypertrophy either does not occur at all, or takes place only during the period of development. The loss of an ovary or testis in adult life can hardly result in an increased activity or hypertrophy of the remaining organ. Extirpation of the larger part of the thyroid gland is not followed by any pronounced hypertrophy of the remaining portion; but, on the other hand, the hypophysis undergoes an enlargement which must be regarded as compensatory. In the case of the *lungs*, an increase in the activity of one portion after the loss of other parts results usually in a permanent overdistention which may lead eventually to atrophy. On the other hand, if during embryonic life a defective development of one lung takes place, the other lung may undergo a compensatory growth, which in the case of total agenesis of one lung may reach a very pronounced degree. For the other organs the general principle may be applied that compensatory hypertrophy is the more perfect the younger the individual. In the case of the brain a compensatory growth of one part after the loss of another is possible only during the early stages of development.

**Hypertrophy from lessened use** occurs in the case of tissues which are subjected to a constant use. Thus, for example, a diminished desquamation of the horny layer of the epidermis leads to its pathological thickening. If, as the result of the destruction of an opposing tooth or an oblique position of the teeth, the incisor teeth in rodents are not worn down by use, they may grow out into long and curved tusks (Fig. 128). Likewise the finger- and toe-nails may reach an abnormal size either from lack of wear or from being left uncut. **Hypertrophy due to defective retrograde change** occurs in organs which after a definite,



FIG. 129.—Elephantiasis scroti in a Samoan nineteen years of age. (After Uthemann, *Deutsche med. Wochenschr.*, 1895.)

period of physiological growth undergo a diminution in size. For ex-

ample, the uterus after pregnancy may remain abnormally large as the result of a failure of involution. The thymus gland, which should begin to atrophy after the tenth year of life, may persist for a much longer period than normally. In bones whose configuration has been brought

about under the influence of the surroundings by means of an alternation of building-up and tearing-down, a **lessening of pressure** may be followed by hypertrophy. In idiots whose brains are deficient in size there is very often seen a hyperostosis of the inner surface of the base of the skull (Chiari). A unilateral hyperostosis of the skull is associated with a unilateral hypoplasia of the brain.

**Frequently repeated or long-protracted mechanical, thermal, chemical, or infectious irritations** give rise to proliferative processes leading to tissue-hypertrophies, which according to their etiology and course must be regarded as chronic inflammations; and such new-formations of tissue may therefore be regarded as an **inflammatory tissue-hypertrophy**. They are characterized very often by the fact that, in the enlargement



FIG. 130.—Acromegaly, according to Erb and Arnold. (Osteoarthropathy, according to Marie and Souza-Leite.)

of the organ, not all of its parts are equally involved in the hypertrophy; but certain individual elements, usually the connective tissue, occasionally also the epithelium, undergo hypertrophy to an especial degree, so that the *structure of the organ* (skin, gland, etc.) is no longer wholly typical.

If the skin is frequently subjected to mechanical irritation and pressure, as, for example, the toes through an ill-fitting boot, there may arise in consequence thickenings of the horny layer of the epidermis, known as *callus* or *corn* (*clavus*). Prolonged irritation of the skin in the neighborhood of the genital openings, caused by gonorrhoeal discharges, may cause a marked elongation and branching of the papillæ with an accompanying thickening of the epithelium, leading to the formation of the warty, cauliflower-like growths known as *venereal warts* or *condylomata acuminata*. Chronic inflammations of the corium and subcutaneous tissue, due to infection or to animal parasites (*Filaria Bancrofti*), not infrequently give rise to extensive fibrous hypertrophies of the tissue known as *elephantiasis* (Fig. 129). Such elephantiasic hypertrophies of the tissue may attain extraordinary proportions. In a similar manner there may occur in the bones, as the result of chronic infectious processes (syphilis,



(for example), extensive hypertrophies characterized by an increased formation of bone-substance.

In the majority of cases of those tissue-hypertrophies which appear during the course of life as acquired formations caused by external influences, the *causa efficiens* may be recognized with more or less certainty; but there are also many cases in which, at the present time, this is either wholly impossible or possible only to a limited extent. For example, there occur *enlargements of the spleen, and of the lymphadenoid tissue* of the lymph-glands and of the lymph-nodes in the mucous membranes, which are of the nature of hypertrophies, whose causes we are unable to recognize. Very imperfect, also, is our knowledge concerning the etiology of the *enlargements of the distal portions of the extremities* (Fig. 130), resembling partial giant-growth, which have been described as **acromegaly** (Marie), **pachyakria** (von Recklinghausen), and *ostéarthropathie hypertrophiante* (Marie). In a part of these cases there are an associated enlargement of the bones of the face and deformities of the spinal column. These changes appear usually in youth or middle age, rarely in old age, and show a gradual development.

So far as anatomical investigations (Arnold, Marie, Marinesco, Thomson, Holsti) have been able to throw light upon this question, the pathological change consists in an increase of all the tissues of the terminal portions of the extremities and of the face, in particular of the bony parts, in that the bones become thicker (Fig. 131) and at the same time become the seat of rounded or pointed exostoses. On the other hand, an increase in the length of the bones has not yet been demonstrated with



FIG. 131.—Skeleton of the hand, with hypertrophic bones, from the case of acromegaly pictured in Fig. 130. (After Arnold.)

certainty in this disease (von Recklinghausen, Arnold), and so the designation *pachyakria* given by von Recklinghausen is well chosen.

The cause and nature of these pathological phenomena are as yet obscure; and the terms mentioned above are not used by all authors with the same meaning. In Germany the designation *acromegaly* is applied to all forms of enlargement of the ends of the extremities which lead to



a paw-shaped deformity of the hands and a gigantesque appearance of the feet, while Marie, who first described these conditions, attempts to draw a sharp line between acromegaly and ostéarthropathie hypertrophiante. He holds that in acromegaly the hands and feet are not deformed, but are symmetrically enlarged, the thickening and broadening diminishing toward the tips of the extremities, so that the terminal phalanges of the fingers and toes are but slightly thickened, while, on the other hand, in ostéarthropathie hypertrophiante the terminal phalanges are enlarged so as to resemble drumsticks, and the articular ends of the bones are irregularly thickened. In the first affection the lower jaw is lengthened, in the latter it is thickened. Marie believes that in many cases ostéarthropathie hypertrophiante is a sequela of inflammatory affections of the lungs and pleuræ, and designates the condition accordingly as ostéarthropathie hypertrophiante pneumique, and holds that the connection between these processes is to be found in the taking up into the body-fluids of poisonous products from the inflammatory foci in the lungs, so that the affection of the bones is to be regarded as an infectious toxic hypertrophic inflammation.

By other authors the causes of acromegaly and ostéarthropathie hypertrophiante are to be sought in a congenital predisposition (Virchow), in disturbances of the sexual function (Freund), in a hypertrophy of the hypophysis (Henrot, Klebs), in persistence of the thymus (Erb, Klebs), or in nervous influences (von Recklinghausen); but none of these hypotheses is adequately supported by anatomical and clinical observations. From the investigations made up to the present time it follows rather that these conditions do not represent an excessive growth similar in nature to a partial giant growth, but are *acquired diseased conditions*, which develop either as independent diseases (acromegaly, pachyakria), or as secondary phenomena in the course of other diseases (ostéarthropathie hypertrophiante pneumique).

The cause of the hypertrophic condition of the thyroid gland, occurring so frequently in many regions, is wholly unknown.

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§ 79. **Regeneration** is that *process through which tissues which have been destroyed are restored*. Under especial conditions this restoration may be brought about by an enlargement of existing parts of cells (regeneration of axis-cylinders), but it is *usually the result of new-formation of cells, which arise in all cases through the division of pre-existing cells*.

Regeneration presupposes that the **injured tissue is capable of proliferation**, and is, moreover, a phenomenon which is in all cases depend-

ent upon **extrinsic causes**. In the fully developed organism in which the different tissues and organs have reached their ultimate differentiation, *each tissue can produce only new tissue of its own kind*. The **specificity of the tissues** is of so decided a nature that epithelial cells can never give rise to connective tissue, nor can the latter ever produce epithelium. Even the individual varieties of epithelium cannot pass over into other types; the ectodermal cells cannot produce intestinal epithelium; kidney epithelium can produce only cells having the character of kidney epithelium, but never liver-cells or those of mucous glands, or connective tissue. Muscle-tissue can arise only from muscle-cells. Nerves and neuroglia can never arise from connective tissue. Only cells which are very closely related to each other can arise from the same parent-tissue or pass into each other. Thus the connective tissue of the periosteum can produce either ordinary connective tissue, cartilage, or bone—that is, tissues which are closely related to each other, and which may be regarded as different modifications of the connective-tissue substance. This power of producing different varieties of connective tissue is, however, not a property of all forms of connective tissue, but is confined, with a few exceptions, to those portions of the connective tissue of



FIG. 132.—The skin-portion of a laparotomy wound sixteen days old (Müller's fluid, Van Gieson's). *a*, Epithelium; *b*, corium; *c*, subcutaneous adipose tissue; *d*, scar in corium; *e*, new epithelium; *f*, scar in adipose tissue.  $\times 38$ .

the skeleton which are capable of proliferation, and to the cartilaginous framework of the bronchi.

In *tissue defects in which only single cells are lost* (as, for example, in the loss of single connective-tissue cells), or in the case of a more extensive destruction of cells *without an interruption in the continuity of the connective*



tissue of the blood-vessels (as the loss of localized areas of the surface epithelium, or a group of gland cells or of pulmonary epithelium), a **complete regeneration**, a *restitutio ad integrum*, may take place, and the tissue be restored to a condition corresponding in all respects to that existing before the injury. After all injuries in which the continuity of the



FIG. 133.—Healing ulcer of the small intestine, with formation of new gland-tubes in the proliferating submucosa (Müller's fluid, hæmatoxylin). *a*, Mucosa; *b*, submucosa; *c, d*, muscularis; *e*, serosa; *f*, remains of the floor of the ulcer not yet covered over with epithelium; *g*, overhanging edge of the ulcer; *h*, portion of floor of ulcer covered with epithelium; *i*, newly formed glands in the submucosa; *k*, deep crypt lined with epithelium.  $\times 18$ .

mesodermal supporting tissue is broken, either with or without an associated injury to tissues of ento- and ectodermal origin, the **regeneration is incomplete**; in that, at the point of injury there is formed a tissue which departs more or less from the normal structure of the affected part, and shows a more or less marked loss of functional capacity as compared to the normal tissue. In general this tissue is a new formation of *connective tissue*, designated as a **scar** (Fig. 132, *d*) or **cicatricial tissue**, in individual organs (as in the heart-muscle) also called a *callosity*, the new connective tissue resembling other formations of connective tissue, but not wholly identical with them. In the course of time it comes through a gradual change more and more to resemble normal tissue. Defects of the skeleton are replaced by scar-tissue which arises from the periosteum and bone-marrow, and by virtue of the peculiar properties of these tissues there develops a new-formation of *bone-tissue* within such scars, the structure coming to resemble closely that of normal bone.

In many cases the *cicatricial tissue* consists purely of *vascularized connective tissue* (Fig. 132, *d*), which later becomes enriched only through the in-growth of *nerve-fibres* and the gradual development of *elastic fibres*. Scars bordering upon ectodermal or entodermal tissue may become covered by a new-formation of epithelium (Fig. 132, *e*). Occasionally the structure of *cicatricial tissue* may undergo a further development, in that *specific tissue-formations* either *grow into it secondarily* or are *preserved in it as remains of preëxisting structures*. The first process occurs most frequently in scars of the mucous membrane of the intestine (Fig. 133), and of glands in the neighborhood of their excretory ducts, and in scars of muscle (Fig. 134). In defects of mucous membranes which are

replaced by scars formed through the proliferation of connective tissue (Fig. 133, *b, f*), the surface is first covered with epithelium (*g, h, k*),

later there develop epithelial ingrowths which bear the character of tubular glands (*i*). Gland-ducts (bile-ducts, ducts of the salivary glands) may grow into the developing scar-tissue, and form new tubes or only solid cords of cells. Such a new-formation of gland-ducts may occur not only in the neighborhood of traumatic injuries, but also in the course of hæmatogenous inflammations of the glands in question.

A new-formation of gland-tissue proper in the neighborhood of scars is, on the other hand, wanting in the case of the majority of glands (liver, kidneys, testicles, ovaries, thyroid, mammary glands, and lungs). Only in the case of the salivary glands does the development of the newly formed ducts lead to the formation of gland-lobules.

In muscle-scars (Fig. 134) new muscle-fibres (*d*) grow from the ends of the old ones (*a*), and penetrate into the scar-tissue, so that the scar becomes gradually replaced by muscle.

The preservation of remains of specific tissue-elements in the area of cicatrization may be observed in the case of both muscles and glands, especially in the periphery of traumatic injuries and anæmic necroses (Fig. 135), and in most cases also in infectious foci of disease. The preserved gland-remains within the scar usually present an atrophic condition (Fig. 135, *b*), but islands of normal tissue (*d*) may also be enclosed, and there arises the possibility that such may undergo a compensatory growth.

In inflammatory processes in glandular organs which are characterized on the one hand by the destruction of the specific parenchyma, and on the other by a new-



FIG. 134.—Scar of muscle and tendon, thirty-two days old (Flemming's solution, Van Gieson's). *a*, Old muscle; *b*, tendon; *c*, scar; *d*, newly formed muscle-fibres.  $\times 100$ .

formation of connective tissue having the character of scar-tissue, there are often seen in the diseased area new-formations of scar-tissue con-



taining atrophic remains of the gland-tissue, and between these, islands of uninjured gland-tissue in a condition of hypertrophy.

The **mass of the scar** is only rarely equal to the mass of the tissue lost, and there persists after the loss of considerable amount of tissue a more or less marked **tissue defect**. Over circumscribed areas of the surface of the skin, mucous membranes, or of glands, the brain, etc., such a defect gives rise to a *cicatricial depression*. Numerous cicatricial defects in an organ may occasion an atrophy of the same characterized by an irregular configuration of the surface.

The loss of the tissues *en masse* of larger portions of the body, as, for example, a toe or a toe-joint, is in man *never again replaced*. Such defects are only closed in by scar-tissue which on the superficial parts of the body becomes covered with surface epithelium.

The **regenerative capacity of tissues** is in man and the mammals slight on the whole. This is dependent upon the fact that the individual tissues show a very high degree of differentiation, and that also in the event of proliferation they do not lose this differentiation to such an extent as to revert to so embryonal a state that, like the cells of the embryonal anlage, they are able to produce different forms of tissue. In spite of this limitation the regenerative powers of the tissues in general are sufficient to restore the continuity of the tissues and to preserve intact the external covering of the

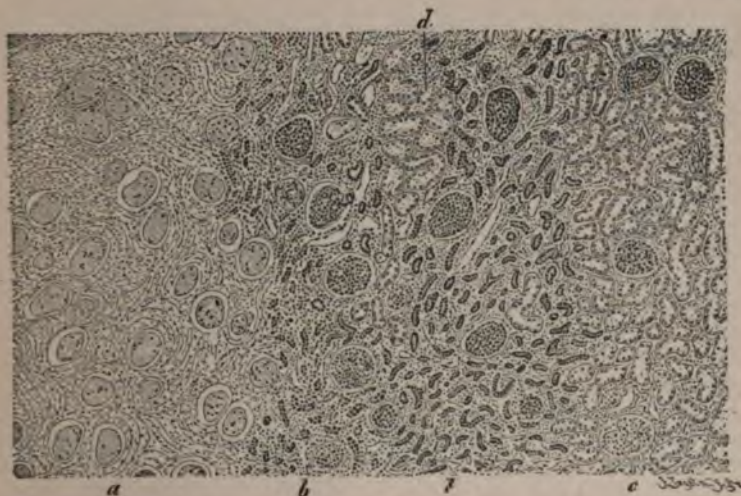


FIG. 135.—Peripheral zone of an embolic scar (Möller's fluid, hæmatoxylin and eosin). *a*, Scar showing obliterated glomeruli, but no tubules; *b*, indurated tissue with atrophic tubules, the glomeruli being preserved; *c*, normal cortical tissue; *d*, island of normal tubules in the scar.  $\times 30$ .

body. If, as the result of a local loss of tissue, the life of the organism be endangered through the inability of the local tissues to restore the lost part, there exists in the case of many organs and tissues (liver, kidneys) the power of compensating for such a loss through the growth of the remaining normal tissue.

In the lower animals the power of tissue-regeneration is much greater than in the case of the mammals; and further is much greater in the earlier stages of ontogenesis, so that, in many animals (tritons, ascidians, echinoderms, teleosts), the first two or even the first four segmentation cells still possess the power of forming an entire embryo. Insects possess during the larval state a very marked power of regeneration, which later is lost.

In the case of protozoa each animal may quickly supplement itself through division. In the case of the fresh-water polypi small fragments of the body may develop again into the entire animal. The angle-worm is able to replace either its tail or head end when these are cut off. The wood-louse can replace its feet and antennae, the snail



its tentacles and anterior extremity, crabs and crayfish their claws and legs. Salamanders are able to restore their legs, eyes, and tails, and lizards and slow-worms their tails, when these are broken off. In the case of frogs, snakes, and fishes, on the other hand, the power of regeneration diminishes as the scale of animal life is ascended, yet this does not happen equally in the case of all animals, and animals closely related to each other may show very different capacities for regeneration. Further, in the same animal the regenerative power is not the same in all organs; for example, in tritons the regenerative capacity of the internal organs is slight. Moreover, the power to form a new portion of the body, as a tail or extremity, for example, does not prove that all the tissues of the portion of the body in question possess an especial capacity for proliferation. In crayfish and crabs the regeneration of the claws and legs takes place only from certain places; in injuries occurring to other points, the new extremity is thrown off only at that place, where a new-formation is possible. In tritons, fractures of the bones heal very slowly, although they are able to reproduce their extremities.

Several years ago *Grawitz* advanced the view ("Über die schlummernden Zellen des Bindegewebes und ihr Verhalten bei progressiven Ernährungsstörungen," *Virch. Arch.*, 127 Bd., 1892; "Atlas der pathologischen Gewebelehre," 1893) that *cells may also arise from intercellular substance*. He holds that, in the formation of connective tissue, cells are transformed into fibres and pass over into a non-nucleated *resting-stage*, in which condition they are invisible under the microscope. From these invisible *slumbering-cells* (*Schlummerzellen*) new cells may arise in inflammation and tissue-proliferation. In this theory of slumbering-cells, *Grawitz* has brought forward as a new teaching, views which were held years ago by *Stricker* and *Heitzmann*, and which had been regarded as buried; but the work done by him and his pupils in his institute contains nothing to substantiate this view. The well-known phenomena of proliferating and inflamed tissues have been described, but no observations have been published which can be regarded as proving that cells may arise from intercellular substance—that is, from invisible slumbering-cells.

§ 80. The **cause of the cell-proliferation** underlying all hyperplastic and regenerative new-formations of tissue varies according to the conditions under which the proliferation occurs. If the new tissue-growth leading to hypertrophy takes its origin from the anlage of the organism concerned or of a portion of the same, no new stimulus is necessary for its appearance; the attainment of the abnormal size is dependent only upon the condition that the new-formation of tissue does not lead to hindrances to growth before the full limit of development is reached. When the proliferation appears first at a later period, something additional is necessary to cause an increase of the normal tissue-formation or to start again into activity the cell-proliferation which becomes quiescent at the close of the period of growth.

In the case of both hyperplastic and regenerative proliferation the "*stimulus*" may consist simply in the **removal of hindrances to growth**. Experience teaches that the majority of the cells of the body possess the power in a given case to divide, even those (connective-tissue cells, gland-cells, muscle-cells) in which the processes of cell-division wholly cease for long periods of time. This cessation of proliferation may be explained by the assumption that the firm combination of the cells with each other and the formation of the intercellular cement inhibit further multiplication. It is also possible that chemical and unknown vital influences act in the same manner. Injuries and degenerations of the tissues of the most varied kinds can, through the loosening of the cells, and through physical and chemical changes in the intercellular cement substance and of the tissue-fluids, cause such changes that all hindrances to the growth and division of cells are removed.

In addition to the removal of hindrances to growth there may be present at the same time a **formative stimulus, which increases both the reproductive capacity and the tendency toward reproduction**. Further, such a stimulus may act independently—that is, without the

removal of the influences inhibiting growth—and this event is to be assumed in those cases in which after the loss of a portion of an organ the remaining portion (liver, kidney) undergoes a compensatory hypertrophy.

The stimuli which are able to excite growth and cell-division are known only in part. In those cases in which their action may be recognized they appear to be *identical with the stimuli which excite or increase functional and nutritive activity*. In the case of the muscles hypertrophy is brought about by increased contraction following nervous excitation. Liver and kidney tissue undergo proliferation when, as the result of a loss of a large area of gland-tissue, the remaining portions are obliged to do an increased amount of work—that is, they must out of the circulating blood produce and secrete those substances which, if life is to be preserved, must be given off either externally or within the body.

Whether there exist still other formative stimuli cannot be said with certainty at the present time. An *increased supply of nutrition*, which has been believed by many to act as a formative stimulus, is not in itself sufficient to excite a new-formation of cells and tissue; it gives rise only to an increased deposit of fat. The cells of the body are not fed, they feed themselves; and an increase of nutrition depends upon the activity of the cells. An *increase of the temperature* of the tissues may hasten the process of cell-division and thereby further tissue-proliferation; but it is doubtful if it can directly excite proliferation in a resting-tissue. The local action of heat, which has been observed to be followed by proliferation (for example, in the skin), produces in the first place changes of a degenerative nature, so that the occurrence of proliferation may be also explained as due to the removal of influences inhibiting growth.

Whether there are *chemically active substances* capable of exciting proliferation, besides those present normally in the body, cannot be decided at the present time. The fact that slight irritation of the skin (painting with iodine) can cause proliferation without preceding degenerative changes makes this appear probable. But it is more probable that, in spite of the negative findings, slight tissue-changes of a degenerative nature do occur, and that through these the inhibitory influences are weakened.

Moreover, it must be noted that even the hypertrophy of muscles and glands following increased activity cannot be absolutely regarded as the direct result of a nervous or chemical stimulus, but rather must we assume that with the *increased labor there is an excessive consumption of cell-elements which excites regenerative processes*, the latter leading not only to a restoration of the parts lost, but also to an increased building-up of the cell-mass and formation of new cells.

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- See also §§ 81-88.

§ 81. The **division of the nucleus and cell-body**, upon which process the formation of new tissue depends, may occur in the first place through **holoschisis** (Flemming), or **direct segmentation** (Arnold)—that is, through a transverse constriction of the elongated nucleus and protoplasm without an increase or characteristic grouping or movement of the chromatin elements of the nucleus. It appears, however, that the direct division of the nucleus leads to a new-formation of tissue—that is, to the production of cells which are able to form new tissue—only when it is connected with that form of cell-division known as **karyokinesis** or



FIG. 136.



FIG. 137.



FIG. 138.

FIG. 136.—Enlarged nucleus. Increase in the chromatin framework.

FIG. 137.—Thick, open skein, with segmentation of the threads into chromosomes; the nucleolus and nuclear membrane have disappeared.

FIG. 138.—Grouping of the completed chromosomes into a star- or wreath-form.

**karyomitosis** (Flemming) or as **indirect segmentation** (Arnold), which is characterized by an *increase of the nuclein or chromatin* (Flemming), and a *definite cycle of changes of form and movements on the part of the latter*.

Usually karyomitosis follows a typical course, as in the normal growth of tissue, but deviations from this are not infrequently seen in pathological new-formations.

A **resting nucleus** consists of an outer covering, the *nuclear membrane*, and the *nuclear contents*. The latter is composed of a colorless *nuclear fluid* and the *nuclear substance*. To the nuclear substance belong the *nucleolus* and *scattered granules and threads* which often form a *framework* staining with nuclear stains.

When the nucleus undergoes **division**, there usually occurs in the first place, an *increase of the chromatin*, and the chromatin *framework* becomes more distinct (Fig. 136). The nuclear substance then forms a



close skein, which with the disappearance of the nuclear membrane and the nucleolus becomes changed into an *open skein* with thick threads (Fig. 137), whose individual components divide themselves into *nuclear segments* (Hertwig) or *chromosomes* (Waldeyer) (Figs. 137, 138).

These segments then group themselves in the equatorial plane of the nucleus with their angles directed toward the centre, forming, when



FIG. 139.



FIG. 140.



FIG. 141.



FIG. 142.



FIG. 143.



FIG. 144.

FIG. 139.—Completely developed mother-star; polar view.

FIG. 140.—Mother-star; equatorial view.

FIG. 141.—Stage of metaphase. Single loops visible, their angles pointed toward the pole; delicate spindle-figure within the nucleus.

FIG. 142.—Daughter-star; side view (nucleus barrel-shaped); spindle-figure in the nucleus and the radial arrangement of protoplasm are visible.

FIG. 143.—Daughter-stars separated; the upper one presenting polar aspect, the lower one a side view.

FIG. 144.—Daughter-skein with fine threads (above), and with lattice-work (below). Completed division of the protoplasm.

viewed from the polar aspect, a wreath-like figure (Fig. 138), and later a star-like figure, lying in the equatorial plane, which has been designated the mother-star (Figs. 139, 140), or the equatorial plate (Fleming).

Sooner or later *two poles* become visible in the interior of the cell—that is, two extremely small spherules, which are known as the *polar* or *central corpuscles* or the *centrosomes*. At first these lie closely together, but later separate from each other and act as centres about which the nuclear elements group themselves. Between these there is formed the *nuclear spindle* (Figs. 141, 142) which consists of fine threads which do not stain with nuclear stains, and converge in the polar corpuscles. In

the neighborhood of the polar corpuscles themselves the granules of the protoplasm present a radial arrangement, giving rise to figures (Fig. 142) which are known as *ray-figures*, *stars*, or *attraction-spheres*. In the following stage of division of the nucleus, which has been designated *metakinesis*, a movement takes place among the chromosomes leading to the formation of unequal-sided loops, whose angles are directed toward the pole. Later the loops, following the direction of the spindle-fibres, move toward the poles and form two stars (Figs. 142, 143) which are known as *daughter-stars*. From the star-figures the daughter-star passes successively through the thick-skein and then the fine-skein stage (Fig. 144, upper part) which finally changes into the nuclear *framework* (Fig. 144, lower part). During the later stages of the process of division a new nuclear membrane is formed.

The **division of the cell-protoplasm** usually takes place at the time the daughter-star changes into the ordinary nuclear condition, and consists in a constriction and separation of the protoplasm (Fig. 144). The radiating figures (Fig. 142) about the centrosomes are to be regarded as evidences of movements within the protoplasm. It is probable that a complicated interrelationship exists between the nucleus and cell-protoplasm; but the nucleus is to be regarded as *the more highly organized substance, as the centre of cellular potentiality*. The nuclei are also the bearers of heredity, while the protoplasm governs the relations of the cell with the outer world.

**Variations from the typical karyokinesis** may consist in the first place in the occurrence of a *pluripolar division* in place of the bipolar, so that two to six or more nuclear spindles and a correspondingly increased number of equatorial plates (Fig. 145, *a*) may be formed. Further, in place of the simple mother-star there may be formed a complicated figure out of the chromatin loops, from which several daughter-stars may be evolved. Not infrequently there occur *asymmetrical divisions of the nucleus* (Fig. 145, *b, c*), particularly in tumors, but occasionally also in regenerative or inflammatory new-formations of tissue.

There also not infrequently occur divisions of the nucleus which are characterized by *abnormal size*, *abnormal richness in chromatin*, and *manifold variations of form*. As types of such division are the large oval or bean-shaped (Fig. 146), knobbed or convoluted, lobulated and branched (Fig. 147), wreath-shaped, linked, basket-shaped (Fig. 148), and otherwise-shaped nuclei. Finally, there are occasionally found in the cells more or less extensive, indistinctly-outlined heaps of granular and lumpy chromatin (Fig. 149).

Such nuclear forms, with the exception of the polynuclear leucocytes, are found particularly in the cells of the bone-marrow, spleen, and lymph-glands, and also in tumors which arise from the bone-marrow or periosteum, but have been also observed elsewhere, particularly in sarcomata. Certain of these forms are appearances due to contraction, and have nothing to do with cell-division. In other cases these changes of size and form precede a division of the nucleus through constriction of certain portions, this process occurring sometimes with, sometimes with-

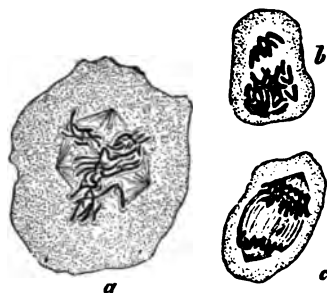


FIG. 145.—*a*, Pluripolar division-figure; *b, c*, asymmetrical division-figures.



out an increase of the chromatin-substance. Arnold has designated the division by constriction with increase of the chromatin as *indirect fragmentation*, that without such increase as *direct fragmentation*. Indirect fragmentation differs from mitosis or indirect segmentation in the lack

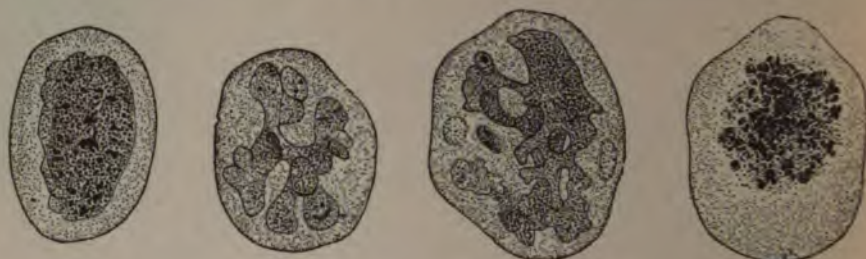


FIG. 146.

FIG. 147.

FIG. 148.

FIG. 149.

FIG. 146.—Cell with oval, slightly knobbed giant-nucleus, rich in chromatin.

FIG. 147.—Cell with lobulated giant-nucleus.

FIG. 148.—Cell with basket-shaped giant-nucleus.

FIG. 149.—Cell with large masses of chromatin. All these cells from a sarcoma of bone. (Strode, Beiträge von Ziegler, VII.)

of an orderly arrangement of the chromatin in threads and in the irregularity with which the separation of portions of the chromatin results in new nuclei.

**Variations in the division of the cell-protoplasm** occur most frequently, either in a *total failure of the protoplasm to divide* after the division of the nucleus has taken place, or in the *delayed division* after that of the nucleus. These phenomena are observed in both mitotic and amitotic division of the nucleus, and lead to the formation of *binuclear cells*. Through progressive nuclear division into two nuclei or through multiple division, there may be formed **multinuclear giant-cells**, which either

persist as such or later undergo further division.



FIG. 150.—Proliferating adipose tissue from the subcutaneous panniculus, twenty-six days after cauterization with trichloroacetic acid (formalin, hæmatoxylin). a, Multinuclear fat-cells; b, proliferating connective tissue.  $\times 300$ .

The cause of the formation of giant-cells may lie in the especial variety of cell. Cells of the spleen and bone-marrow and of tumors arising from the bone show this phenomenon with especial frequency. Proliferating fat-cells likewise often form multinuclear giant-cells (Fig. 150, a). Furthermore, this phenomenon is often seen when pro-

liferating cells lie upon the surface of some foreign body. In the cellular new-formations caused by the tubercle-bacillus the formation of multinuclear giant-cells is a typical phenomenon. The adhesion of the

cellular protoplasm to a firm body, the enclosure by the cell-protoplasm of large foreign bodies (also fat-drops), and also the partial degeneration of the protoplasm caused by bacteria, may be the factors hindering the division of the cell.

Occasionally the protoplasm of the cell, during division, forms also **buds** or **offshoots**, and this phenomenon may occur either before or after the division of the nucleus. Into the buds or offshoots nuclei may later migrate (see new-formation of blood-vessels).

According to *Rübl*, whose studies were carried out on the large nucleated cells of cold-blooded animals, the closely wound mother-skein consists of several pieces, all of which are bent back to one end of the nucleus (called the polar field) (Fig. 151, *a*), leaving the pole itself free, while at the opposite end (the opposite polar field) (*b*) they extend across the pole. The transition from the close to the open skein (Fig. 152) is brought about by the threads becoming thicker and shorter, at the same time these divide so that the number of loops becomes increased.

The stage of the *segmented skein* (Fig. 153), which follows next, is characterized especially by the *longitudinal fission of the separate loops*, whereby the chromatin-sub-

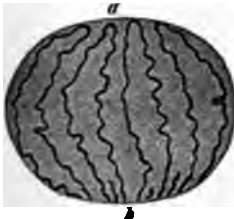


FIG. 151.

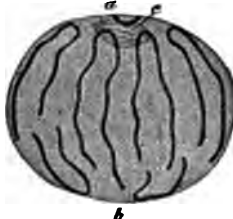


FIG. 152.



FIG. 153.

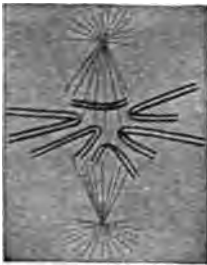


FIG. 154.



FIG. 155.

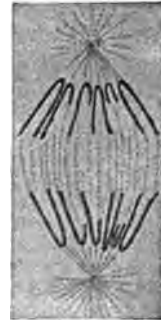


FIG. 156.

FIG. 151.—Close skein; lateral aspect.

FIG. 152.—Open skein; lateral aspect.

FIG. 153.—Final stage of the skein, with splitting of the threads.

FIG. 154.—Mother-star.

FIG. 155.—Metakinesis.

FIG. 156.—Daughter-stars.

stance becomes divided into two equal parts. The further course of the karyokinesis is essentially directed toward the uniting of each half of chromatin threads into a new group.

During the stage of the coarse open skein there has already begun to develop in the neighborhood of the polar field a *spindle-shaped figure* (Fig. 152, *c*), consisting of delicate threads which terminate in small shining bodies, the *centrosomes*. Later, this spindle wanders into the nuclear substance (Fig. 153), and exerts a directing influence upon the chromatin threads. In the plane of its equator the division of the nucleus later takes place.

In order to initiate the process of division the loops of threads group themselves about the equator of the spindle in such a way that their angles point toward the centre

of the spindle, thus completing the mother-star (Fig. 154). At the same time the nuclear membrane disappears while from the poles of the spindle radially-arranged fibrils (Figs. 154-156) stream out into the cell-protoplasm (*cytaster*, *attraction-sphere*).

*Metakinesis* is characterized by a separation of the daughter-threads arising from the longitudinal fission, which up to this time have remained parallel with each other; and it is completed sometimes by the threads of each pair (Fig. 155) moving toward the opposite poles. The new loops arising in this way have their angles directed toward the poles.

The *daughter-stars* (Fig. 156) are formed by the chromatin loops that have moved toward the poles of the spindle.

The *daughter-skein* (dispirem of *Flemming*) arising from the daughter-stars consist of loops of fibrils which are bent back at the point where the poles of the spindle are situated (Fig. 157, *a*) and leave one polar field (*c*, *d*) free from loops.

The transition from the skein into the framework of the resting-nucleus (Fig. 157, *b*) follows (*Rabl*) the division of the cell-protoplasm, and is initiated by the chromatic fibres sending out processes. According to *Flemming*, *Strassburger*, and *Retzius*, the chromatin threads unite directly with one another.

The significance of the nuclear corpuscles (nucleoli) is still a matter of dispute. *Flemming* and *Pfitzner* believe that they are different from the nuclear framework, while others regard them as much-thickened nodal points of the fibrils of the framework. In what way they are again formed after the division of the nucleus is not known.

The *nuclear framework* forms at its periphery a thick, basket-like layer, on the outer side of which lies another membrane, which does not stain.

The spindle-figure, whose fibres stain but slightly with nuclear stains, is derived, according to *Flemming* and *Hertwig*, from the above-mentioned achromatic substance of the nuclear framework, while *Strassburger* believes that it arises from the cell-protoplasm.

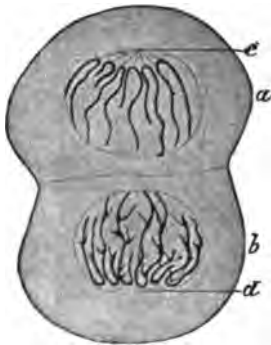


FIG. 157. — Daughter-skein (*a*), and daughter lattice-work (*b*); *c*, polar area with the remains of the spindle; *d*, polar area.

The *centrosomes* or *polar corpuscles*, which are always present in nuclear segmentation, are found also in resting-nuclei; but up to the present time they have been demonstrated only in a part of the cells, most frequently in lymphocytes and the giant-cells of the bone-marrow. At the same time the investigations of *van Kölliker*, *Flemming*, *M. Heidenhain*, and others make it probable that the centrosomes are present in all cells, lying sometimes in the nucleus, sometimes in the protoplasm, where on account of their small size they can be demonstrated only with difficulty. (The centrosomes do not stain with the ordinary nuclear stains, but with acid aniline dyes, as acid fuchsin and safranin.) Whether they are elements of the protoplasm or of the nucleus has not yet been decided. According to *van Beneden*, *Boveri*, and *Rabl*, the mitosis of the nuclear substance is to be referred to a direct drawing-apart, starting from the divided centrosomes and brought about by the agency of the achromatic fibres. According to *M. Heidenhain*, the central corpuscles are sharply circumscribed granules which possess the power of assimilation, of growth and of

multiplication by budding, whereby they are accustomed to form groups. Either alone or united in groups, they can form the central point of insertion of a system of contractile fibres (spindle-figures, microsome rays), and consist of a specific substance (in a chemical sense) which is not present elsewhere in the cell.

*Flemming* designates the cell as a circumscribed mass of living matter, and distinguishes in the *cell-body* two different elements, one of which, the *protoplasm* (*filarmass*, *mitome*, *framework*) is somewhat more highly refractive and is arranged in the form of threads, while the other, the *paraplasm* (*interfilarmass*, *paramitome*) fills in the remaining space. The products of metabolism, granules, vacuoles, and other inclusions, which the cells at times contain do not belong to the cell-substance. *Arnold* advances the view that many threads contain *granules* (*microsomes*, *plasmosomes*) or break up into rows of granules which are united by connecting links. The *plasmosomes* may also become changed into granules (see § 66).

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## II. The Processes of Hyperplasia and Regeneration in the Various Tissues.

§ 82. The morphological changes in the **regeneration and hyperplasia of epithelium** are relatively simple. The karyomitoses (Fig. 158, *a-d*) show for the chief part a typical course. The division of the protoplasm takes place either in the later stages of the process of nuclear division or follows after the same. Occasionally processes are first formed from the proliferating epithelial cells, and into these nuclei later wander. Through separation from the mother-cell these processes may become independent cells.



*Epithelium arises only from epithelium*, and, moreover, the different varieties of epithelium do not pass over into one another. It is to be noted, however, that under certain conditions—for example, in cases of inflammatory irritation of long standing—the regenerating epithelium may change its character, so that pavement epithelium may occasionally be developed in places which originally possessed stratified ciliated columnar epithelium. This may occur, for example, in the case of cicatrization of ulcers in the trachea. Defects of ciliated columnar epithelium are in the first place repaired by low columnar or flat cells which later become changed into high columnar cells.



FIG. 158.—Regenerative proliferation of the epithelium of bile-ducts, in the neighborhood of a wound of the liver five days old (Flemming's solution, safranin). *a*, Enlarged nucleus of epithelial cell, with increase of chromatin; *b*, epithelial cell with mother-skein; *c*, epithelial cell with mother-star; *d*, epithelial cell with daughter-skein; *e*, connective-tissue cell with daughter-star.  $\times 400$ .

Small losses of substance in the superficial epithelium are usually quickly replaced through regenerative growth of the neighboring cells (Fig. 159, *d*, *d*<sub>1</sub>, *d*<sub>2</sub>). In such cases it may be seen that the epithelium bordering upon the defect quickly pushes over the denuded surface and begins to proliferate. The division of the nucleus and cell-protoplasm takes place not only on the edge of the defect, but also at some distance from it. In the intestine the loss of the superficial epithelium is quickly made good by a proliferation of the epithelial cells situated in the deep parts of the crypts of Lieberkühn. Likewise glandular epithelium—for example, in the liver or kidneys—is quickly restored after loss, provided the structure of the tissue—that is, of the basement membrane



FIG. 159.—Healing of blister caused by a burn (alcohol, alum-carmin). Section through the skin of a cat's paw, forty-eight hours after the production of a blister. *a*, Horny layer; *b*, rete Malpighi; *c*, corium; *d*, newly formed epithelium; *d*<sub>1</sub>, *d*<sub>2</sub>, newly formed epithelium already differentiated into different layers; *e*, old, degenerated epithelium; *f*, pus-cells; *g*, exudate; *h*, sweat-glands.  $\times 25$ .

upon which it rests—is not changed. After destruction of liver-tissue both liver-cells and the epithelium of the bile-ducts (Fig. 158) proliferate, and the cell-division attendant upon an injury to the liver may



extend to a relatively great distance from the wound. Experimental wounds of the liver heal through the formation of connective tissue, into which only offshoots of the bile-ducts penetrate, while a local reproduction of liver-tissue does not take place. Likewise, in the kidneys, testicles, thyroid, and ovary the local production of glandular tissue in the connective-tissue scar is very slight or wholly wanting, and does not lead to the formation of functioning tissue. In the salivary and mucous glands, on the other hand, there occurs a branching of the gland-ducts, and a new-formation of glandular alveoli.

When portions of the mucosa and submucosa of the intestine are lost as a result of ulcerative processes, there occurs during the process of healing a glandular proliferation, which, according to the nature of the defect, forms partly typical, partly atypical (Fig. 133, *i*) glands which grow into the submucosa. The new gland-formation takes its start from the old glands, whose epithelium pushes over the edge and base of the ulcer (Fig. 133, *g, h*) and also lines any depressions which may happen to be present (*k*). In a similar manner ulcerative defects of the stomach mucosa are again made good; and even extensive ulcers may become covered over with a gland-containing mucosa, although the glands do not for the most part show a typical development—that is, are not transformed into characteristic gastric glands.

The epithelial portions of the uterine mucosa which are in part lost, as a physiological process, during menstruation and parturition, and are afterward replaced, may be restored in a similar manner in the healing of pathological defects of the endometrium. The new-formation of epithelium takes its origin from the glandular remains.

**Compensatory hypertrophy** of a kidney or liver, as the result of the loss of kidney- or liver-tissue, is brought about through the *formation of new gland-cells, and the enlargement of existing renal tubules, or liver-rods respectively*. After extirpation of one kidney the beginnings of compensatory hypertrophy are recognizable even on the third day, by the appearance of division figures in the epithelium of the urinary tubules; and there then follows a further proliferation, continuing for some time, of the epithelium of the uriniferous tubules and glomeruli as well as of the cells of the vessel-walls, as a result of which all the parts become enlarged. In the liver the lobules are enlarged, but no new-formation of these occurs.

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§ 83. The new-formation of blood-vessels plays a very important rôle in hyperplasia of the most varied tissues. If connective tissue, bone, or glandular tissue is to be reproduced in any considerable amount, the new-formation of blood-vessels is essential, since it is only through these that sufficient nutrition can be brought to the growing tissue.

The development of new blood-vessels takes place through the **formation of offshoots** from the sides of the walls of preëxisting vessels (Fig. 160). In the vessel-wall there occurs a **proliferation of cells, particu-**

larly of the endothelium (Fig. 161), in which the division of the nucleus occurs by **karyomitosis**.

As the first step in the formation of a new vessel, there is seen on the outer side of some capillary loop a tent-like elevation which terminates in a fine protoplasmic thread (Fig. 160, *a*), standing out from the vessel, and gradually becoming longer and longer, while the granular mass like-



FIG. 160.—Development of blood-vessels by formation of offshoots; from preparations taken from inflammatory granulations. *a, b, c, d*, Different forms of offshoots, some solid (*b, c*), others becoming hollow (*a, b, d*), some simple (*a, d*), some branching (*b, c*), some without nuclei (*a, d*), some with nuclei (*b, c*); *d*, offshoot to which fibroblasts have applied themselves.

wise grows out at the same time. There is thus formed at the beginning a *solid granular arch of protoplasm, which ends in a protoplasmic thread (a)*, and after a certain time comes to contain nuclei. This thread may penetrate into another vessel, or may unite with some other arch which it meets, or finally may return to the same vessel from which it started.

Further, from the solid arch itself new secondary arches may spring (Fig. 160, *b, c*), or at its end there may be formed a club-shaped swelling (*c*).

The originally solid arch becomes hollow after a certain time (*b, a*) through the liquefaction of its central part, and the space thus formed either immediately or very soon comes to communicate with the lumen of the blood-vessel (*a*), or else there is developed from within the vessel an extension of the vessel-lumen into the arch. The blood of the mother-vessel finds its way at once into the cavity of the daughter-vessel and widens it. As the hollowing-out process constantly advances and extends to the point of entrance of the protoplasmic arch into another blood-vessel, there is finally formed a new capillary loop permeable for blood.

Immediately after the opening of a way for the blood the capillary tube possesses a homogeneous wall. After a certain length of time the protoplasm groups itself about the nuclei, which have in the mean time

divided and multiplied in the wall, so that ultimately the capillary comes to be made up of flattened endothelial cells. As Arnold has shown, the boundaries of the individual flattened endothelial cells may be made visible through the injection of a solution of silver into the vessel. At this time the wall for the greater part appears much thickened, partly from the proliferation of the cells of the vessel-wall, but also partly from the fact that formative cells from the neighborhood heap themselves upon the surface of the young vessel (Fig. 160, *d*), adapt themselves to the wall, and so strengthen it.

At the time of the formation of the offshoots, the endothelial cells of the capillaries are swollen, so that they form cells rich in protoplasm, which often in proliferating tissues reach such a size that the cross-section of a capillary looks not unlike a gland-tube lined with epithelium (Fig. 162, *d*). At the same time division-figures appear in the endothelium (Fig. 161, *a-c*), and later the division of the nucleus and cell-protoplasm takes place.

Just in what relation this proliferation stands to the formation of the offshoots is not yet clearly understood; but doubtless the latter spring from proliferating cells and represent cell-processes of the same. The proliferation of endothelium, on the other hand, does not always lead to a new-formation of vessels, but may result only in a thickening of the vessel-wall and finally in an obliteration of the lumen.

In the transformation of newly formed capillaries into arteries and veins—a change which must always occur in the case of extensive new-growths—the increase of tissue is the result of the continued proliferation of the cells of the vessel-wall. The individual elements of the arteries and veins are then developed from this formative material through especial processes of differentiation.

Three varieties of new-formation of blood-vessels are described by different authors—the primary, secondary, and tertiary, the last of which is described above.

In the primary form the cells of the germ-tissue are directly transformed into red blood-cells and the elements of the blood-vessel walls, in such a manner, that the germ-cells unite to form strands whose axial portion becomes changed to red blood-cells, while the peripheral parts become the vessel-wall. Such a form of vessel-development, which occurs in the area *germinativa*, does not take place pathologically.

In the secondary form, according to Billroth, O. Weber, Rindfleisch, and Cornil (*l.c.*, § 82), spindle-cells unite to form cords in such a way that a canal is formed between them. Whether such a mode of vessel-formation actually occurs, appears doubtful.

It is probable that these observations are based upon errors due to the fact that spindle-cells very early arrange themselves upon the vessel-buds, cover them up, and form cords of cells about them.

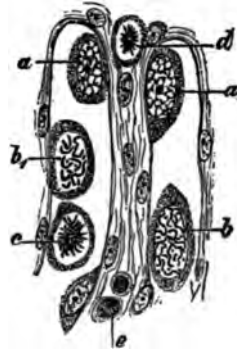


FIG. 161.—Two vessels of the papillary body, whose endothelial cells are in process of proliferation (six days after painting the back of the foot with tincture of iodine) (Flemming's solution, safranin, and picric acid). *a*, Nucleus with chromatin framework; *b*, *b*, skein-forms; *c*, mother-star; *d*, connective-tissue cell with nuclear division-figure; *e*, mononuclear leucocytes.  $\times 350$ .

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§ 84. The **connective-tissue structures** are almost all capable of both hyperplastic and regenerative proliferation. This is especially true of unformed and formed connective tissue, the periosteum and the bone-marrow; while cartilage possesses but a slight regenerative capacity, and fully developed bone none at all. Usually proliferating fibrous connective tissue gives rise to fibrous tissue, both in the case of independent formations of connective tissue and in the supporting tissue of the glands, lungs, lymph-glands, and brain. The periosteum, bone-marrow,

perichondrium and cartilage produce in addition to fibrous connective tissue and marrow-tissue also cartilage and bone.

**Hyperplastic and regenerative proliferations** of the connective tissues are ushered in by *cell-division* in the course of which the karyomitoses, described above (Figs. 158, *f*; 161, *d*; 162, *b*, *c*), occur.

After injuries of the tissue these proliferations begin very soon, as, for example, in wounds of the skin, or in fractures of the bones; in the latter case even as early as the second day single cells of the periosteum have become enlarged and show

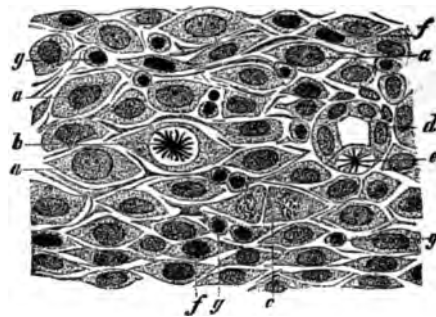


FIG. 162.—Proliferating periosteum, four days after fracture of a bone (Flemming's solution, hæmatoxylin). *a*, Pale formative cells with large nuclei; *b*, osteoblast with division-figure; *c*, two cells shortly after division, showing thread-akin in nucleus; *d*, blood-vessel with proliferating endothelium; *e*, endothelial cell with nuclear division-figure; *f*, small, deeply staining formative cells; *g*, leucocytes.  $\times 350$ .

division-figures. Besides mitoses, direct division of the nuclei also takes place.

When only a few cells are destroyed in the event of an injury to the tissue newly formed cells replace those destroyed without the occurrence of any marked structural changes in the tissues. If, on the other hand, under pathological conditions, a considerable amount of new tissue is produced within a short time, the proliferating cells form an **embryonic tissue** consisting essentially of cells and blood-vessels (Fig. 162). The extent of such formation naturally varies greatly and is dependent partly upon the capacity of the tissue for proliferation, and partly upon the lesion leading to the proliferation. Thus, for example, the periosteum, proliferating after the fracture of a bone, forms a continuous layer of proliferating embryonic tissue (Fig. 162), while proliferating cartilage, on the other hand, produces only small foci of embryonic tissue consisting of a limited number of cells.

Proliferating cells are always larger than the cells of fully developed and resting connective tissue which are relatively poor in protoplasm.

They contain large, bladder-like nuclei with nucleoli, and for the greater part only one or two nuclei (Figs. 162, 163), though multinuclear cells (Fig. 163, *c*.) the so-called *giant-cells*, also occur.

Since all these cells are the antecedents of the future tissue they are designated as **formative cells**, those giving rise to fibrous connective



FIG. 163.—Isolated cells from a granulating wound (picrocarmine). *a*, Mononuclear; *a*<sub>1</sub>, polynuclear leucocytes; *b*, different forms of mononuclear formative cells; *c*, formative cell with two nuclei; *c*<sub>1</sub>, multinuclear formative cells; *d*, formative cell in stage of connective-tissue formation; *e*, fully developed connective tissue.  $\times 500$ .

tissue are called **fibroblasts** (Figs. 163, *b*, *c*, *d*, *e*; 164, *a*), while those forming cartilage and bone are known as **chondroblasts** (Fig. 165, *a*, *c*) and **osteoblasts** (Fig. 162, *a*, *b*, *c*) respectively.

The shape of the formative cells varies greatly (Fig. 163, *b*, *c*, *d*, *e*), and is dependent, partly upon intrinsic causes—that is upon spontaneous changes of form—partly upon the influence of the environment, which under certain conditions compels the cells to take certain definite forms. The cells producing connective tissue usually present the greatest variety of form.

When **connective tissue** is developed from a cellular embryonic tissue, either *fine fibrillæ* (Fig. 163, *d*, *e*) appear at once in certain parts of the cell-protoplasm, or there is formed first a *homogeneous intercellular substance* (Fig. 164, *b*) in which the fibrillæ later appear. The formative cells at the same time diminish in size, and come to lie, for the most part, in small clefts (Fig. 163, *e*) in the ground-substance.

**Elastic fibres** first appear in newly formed connective tissue at a late stage, and at the beginning form very fine fibrillæ, which (Fig. 165, *b*) represent processes of older thicker fibrillæ (*a*). It is difficult to trace their origin. Whether they arise from the cells, or represent a differentiation-product of the fibrillar intercellular substance is yet a matter of dispute.



FIG. 164.—Development of connective tissue from fibroblasts (Müller's fluid, picrocarmine). *a*, Fibroblasts; *b*, hyaline ground-substance with scattered fibrillæ; *c*, fibroblast with adjacent fibres.  $\times 400$ .



The connection of the newly formed fibres with older elastic fibres speaks rather for the latter hypothesis.

They develop most abundantly in newly formed connective tissue in the blood-vessels and in the skin, but such a new-formation of elastic



FIG. 165.—Scar of the skin, two years old, showing newly formed elastic fibres (alcohol, orcein). *a*, Corium with normal elastic fibres; *b*, scar with newly formed elastic fibres.  $\times 500$ .

fibres occurs also in other regions, as, for example, in connective-tissue proliferations inside of glands.

In the development of **hyaline cartilage** there appears between the cells a hyaline basement-substance (Fig. 166, *f*), while the *chondroblasts* (*c*) at the same time assume a more rounded form (*d*). In time the ground-substance increases, the chondroblasts grow smaller and come to lie in rounded cavities whose walls are denser than the rest of the ground-

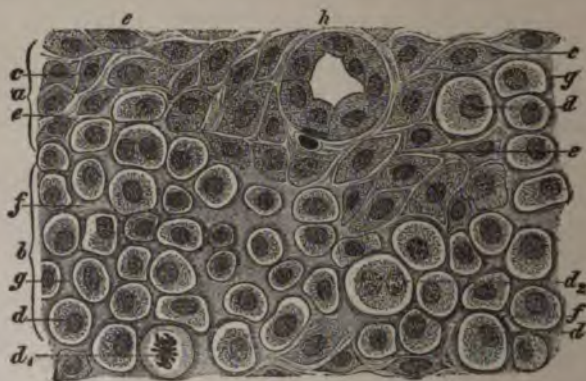


FIG. 166.—Peristosteal formation of cartilage in a fracture five days old (Flemming's solution, hæmatoxylin, glycerin). *a*, Cellular embryonic tissue; *b*, cartilage; *c*, proliferating periosteal formative cells; *d*, cartilage-cells; *d*<sub>1</sub>, *d*<sub>2</sub>, nuclear division-figures in cartilage-cells; *e*, ground-substance of embryonic tissue; *f*, ground-substance of the cartilage; *g*, capsule of cartilage-cells; *h*, proliferating endothelium of a blood-vessel.  $\times 320$ .

substance and later form the part of the basement-substance called the *cartilage-capsule* (*g*).

In the development of **bone** from cellular embryonic tissue there appears between the formative cells a dense homogeneous or fibrillated

basement-substance (Figs. 167, *e, f*; 168, *c*), which later on becomes impregnated with lime-salts. When the ground-substance between the osteoblasts is already of a loose fibrillar nature (Fig. 167, *d*) the transition

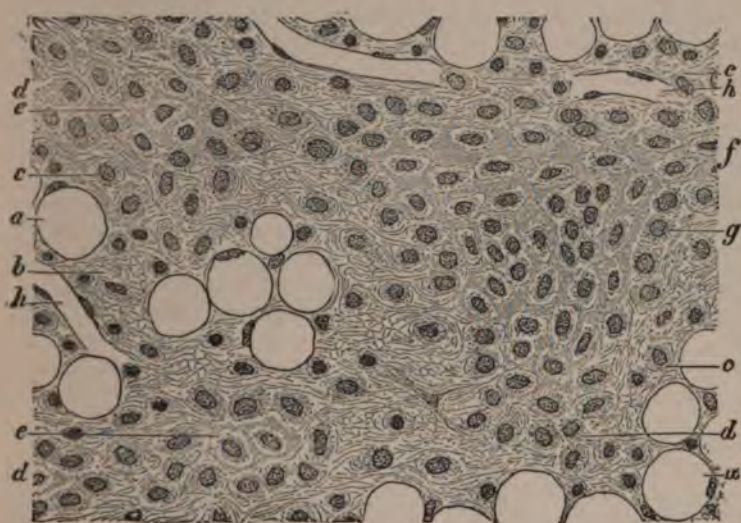


FIG. 167.—Myelogenous formation of bone from masses of osteoblasts (Müller's fluid, picric acid, hæmatoxylin, carmine). Preparation from the inner callus of a fourteen-day old fracture of the fibula of a man twenty-five years of age. *a*, Fat-cells of the bone-marrow; *b*, bone-marrow containing no fat; *c*, scattered osteoblasts; *d*, groups of osteoblasts; *e*, first step in the formation of the ground-substance of bone; *f*, developing trabeculae of bone; *g*, layer of osteoblasts lying upon the newly formed trabeculae of bone; *h*, blood-vessel.  $\times 150$ .

into bone-tissue is brought about through a thickening of the ground-substance (*e, f*). Through chemico-physical changes of its ground-substance cartilage may become directly transformed into bone (see Metaplasia). The osteoblasts come to lie in irregular spaces furnished with processes (Figs. 168, *c*; 169, *b*), and are then usually known as *bone-corpuscles*. In



FIG. 168.—Formation of osteoid trabeculae from the proliferating periosteum. Preparation from a fourteen-day old fracture (Müller's fluid, picric acid, hæmatoxylin, carmine). *a*, Fibres belonging to the outer periosteum; *b*, embryonic tissue; *c*, osteoid tissue; *d*, cartilage; *e*, bone-marrow.  $\times 75$ .

extensive development of cellular embryonic tissue the change into bone is limited to certain parts of the tissue, so that within the embryonic tissue trabeculae (Fig. 168, *c*) are formed, which, so long as they do not

undergo full development into bone and do not become calcified, are called **osteoid trabeculae**. The embryonic tissue (*b*) lying between becomes changed into **marrow-tissue** by the cells becoming united to each other through processes, while between them there appears a fluid basement-substance, in which round-cells later appear embedded. If only a little bone-tissue is to be formed and deposited upon old bony trabeculae, the *osteoblasts* (Fig. 169, *c*) arrange themselves upon the surface of the latter, and these later on produce bone (*b*) in the manner described above.

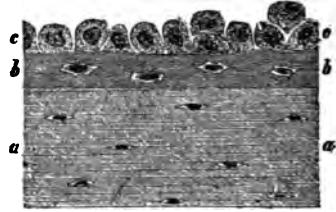


FIG. 169.—Formation of bone, through deposits made by osteoblasts upon the surface of old bone (Müller's fluid, picric acid, hæmatoxylin, carmine). *a*, Old bone; *b*, newly formed bone; *c*, osteoblasts.  $\times 200$ .

**Mucous tissue** arises from embryonic tissue through the formation of a mucin-containing, homogeneous, gelatinous basement-substance between the cells which at least in part become united through processes to form a network.

**Lymphadenoid tissue** can develop from embryonic tissue through the formation of a supporting reticulum from a part of the cells, while lymphocytes gather in the meshes of this network, the spaces of which contain lymph. In *injured lymph-glands*, the cells of the reticulum proliferate and form *ordinary fibrous tissue*; a reticular development of this connective tissue into lymphadenoid connective tissue either does not take place at all or but to a very slight degree.

**Spleen-tissue** is not formed anew after injury to this organ; the wound heals through ordinary *cicatrization*. Compensatory hypertrophy does not take place after the removal of large portions of the organ.

**Fat-tissue** arises through the taking up of fat into the cells of embryonic tissue, mucous tissue or fibrous connective tissue, the cells becoming changed into fat-cells through the confluence of the fat-droplets which they take up.

The **basement-substance** of the tissues described above is a **product of the protoplasm of the formative cells**. Whether in its formation portions of the cell-protoplasm are directly changed into basement-substance, or whether they secrete the latter, or separate it from the intercellular fluid, is often a difficult question to answer; but it is probable that only the first two methods of formation occur. In suitable specimens it may often be seen that the *fibrillae*, both of the connective tissue and of osteoid tissue, as well as of newly-formed cartilage tissue *are connected with cells*—that is, they represent simple or branched processes of the same, or they may even enter into the granular protoplasmic substance (Fig. 163, *d*), thus forming an integral part of the cell-body. In other cases such a connection cannot be demonstrated.

With the further differentiation of the fibrillar basement-substance, the fibrillae, to a great extent, become separated from the protoplasm.

*Fibrillar connective tissue* can develop from any of the connective tissue possessing the power of proliferation, but there must first be formed an intermediate stage of embryonic tissue.

**Bone** arises chiefly from the periosteum, perichondrium, and bone-marrow; but may also develop from other connective-tissue substances, as, for example, from the intermuscular connective tissue.

**Cartilage** arises chiefly from proliferating perichondrium, periosteum, bone-marrow, and cartilage itself; but may also be developed from other connective tissues, as, for example, in connective tissue of the testicle and parotid. The cartilage cells near a lesion may under certain circumstances proliferate and form a large-celled embryonic



tissue, but this does not reach any great size. In the proliferation of cartilage-cells within cartilage the cell-multiplication and new-formation of cartilage occur in the same way as in the physiological proliferation of this tissue. Very often the newly-formed cartilage is only a transitory tissue, and is soon transformed again into bone and marrow-tissue, or into connective tissue.

New *lymphadenoid tissue* may, under pathological conditions, arise either from lymphadenoid tissue, or fat-tissue (*Bayer*) or from fibrillated connective tissue. It is formed from the latter most frequently in the connective tissue of the mucosa and submucosa of the intestinal tract, as well as in the glandular organs; rarely in the intermuscular connective tissue.

*Mucous tissue* may develop from any proliferating connective-tissue substance, but rarely appears in large masses, and is usually a transitory form passing over either into fat or connective tissue.

*Fat-tissue* develops particularly in those regions normally containing fat, but occurs also at times in other places, for example, in the reticular connective tissue of atrophic lymph-glands, in the perimysium internum of atrophic muscles, etc.

The close relationship of the connective-tissue substances to each other enables the different forms to pass from one to another without the need of an intermediate stage of embryonic tissue produced by proliferation. Further details in regard to this point are contained in the next part.

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§ 85. The new-formation of the white blood-cells occurs, in the first place, within the lymphadenoid tissue of the lymph-glands, spleen, and the intestinal tract, and there are contained within the lymph-nodes areas sharply outlined from their surroundings, in which there are

always present numerous cell-division figures which belong for the most part to free cells. These areas have been designated germ-centres (Flemming). Further, leucocytes are also produced in the bone-marrow and gain entrance to the blood through the vessels of the marrow. Moreover, division of leucocytes occurs in the lymph-vessels of the lymph-glands and the tissues, and there is now no doubt that leucocytes may divide in the circulating blood and in the tissue-spaces. Whether there may arise from the proliferation of connective-tissue cells such forms of cells as have the power of wandering into the blood-vessels, and which there may be regarded as white blood-corpuscles, is not yet settled.

The division occurs chiefly through mitosis; but amitotic division also takes place, and upon this phenomenon depends the fact that a large part of the leucocytes contain peculiar lobulated, wreath-shaped nuclei or even nuclei which have broken up into small fragments.

Mitotic division is the form of division which leads to the formation of viable cells. In how far amitotic division (fragmentation of the nucleus) is followed by a cell-division is a difficult question to decide, but it is to be assumed that leucocytes with fragmented nuclei represent elements undergoing a retrograde change. Consequently the transformation of mononuclear into polynuclear leucocytes is to be taken as an evidence of approaching dissolution.

The new-formation of red blood-cells takes place (Bizzozero, Neumann, Flemming) through mitotic division of nucleated young forms of red blood-cells, the **erythroblasts**. In the human adult this process is limited to the bone-marrow, and the same is true in the case of mammals, birds, reptiles, and the tailless amphibia, while in the tailed amphibia and in fishes the spleen also takes part in the formation of red cells. In embryos the formation and multiplication of red cells occurs throughout the entire vascular system: later this activity is confined to the spleen, liver, and bone-marrow, and finally to the last alone.

Neumann holds that the multiplication of the young forms of the red cells occurs in the lymphoid marrow. According to Bizzozero and Denys the increase, under normal conditions, takes place only in the vessels of the marrow, and the complete development of the red cells is carried out in the same location. The change of the nucleated cells into the non-nucleated is brought about, according to the majority of observers, by the disappearance of the nucleus. According to Rindfleisch, Howell, Malassez, and Maximow the nucleus is extruded from the cell. According to Maximow there may be distinguished in the protoplasm of erythroblasts possessing old pyknotic nuclei, a granular substance lying close to the nucleus and a homogeneous peripheral substance. After the extrusion of the nucleus the inner granular substance, which stains with neutral red and other stains, remains preserved for a time, but vanishes during the ripening of the red blood-cells.

The origin of the nucleated red cells has not yet been satisfactorily explained. According to Bizzozero the young forms of the red cells are



FIG. 170.—Section from the germinal centre of a mesenteric gland (after Flemming). *a*, Large, *b*, small leucocytes; *c*, karyomitoses; *d*, direct nuclear division or nuclear fragmentation; *e*, cells containing near the nucleus "tingible bodies" and small yellow pigment granules, whose significance is unknown.  $\times 400$ .



of a peculiar type which constantly contain hæmoglobin and have no colorless antecedents. Denys, Löwit, Howell, and Pappenheim hold, on the contrary, that they arise from nucleated, colorless cells containing no hæmoglobin (basophile leucocytes according to Pappenheim), which according to Denys increase within the marrow-vessels; while Löwit, on the other hand, holds that the colorless antecedents of the red cells, dividing by mitosis, and which he calls erythroblasts, occur in the lymph-glands and spleen, as well as in the bone-marrow, and are found both within the vessels and in the meshes of the reticular tissue.

Flemming, who agrees with Bizzozero concerning the hæmoglobin content of the nucleated young red cells, is inclined to assume that the young forms present in later life are direct descendants of the young forms of the embryonic period. Neumann holds that this hypothesis is not sufficient to explain all the phenomena of later life; as, for example, the replacement of fatty marrow, which contains no nucleated red cells, by blood-forming lymphoid marrow, and the formation of blood-cells in newly developed marrow. He finds himself driven to the assumption that either a development of the nucleated red blood-cells takes place from the leucocytes of the blood which are carried to the marrow after birth by the arteries, or that they arise from the tissue-elements of the bone-marrow.

In case of an increased formation of red cells, as occurring after loss of blood, and also in severe chronic anæmia and leukæmia, nucleated red cells may appear also in the circulating blood outside of the bone-marrow, while under normal conditions they are not found there. The fatty marrow acquires in such cases the character of lymphoid marrow, and this change is brought about by the disappearance of the fat through dilatation of the vessels with increased supply of blood, and through an increase in both the colorless and red cells of the marrow.

*Ehrlich* (*Zeitschr. f. klin. Med.*, i.; *Charité Annal.*, 1884; *Verhandlung d. Phys. Ges. zu Berlin*, 1878-79; *Deutsch. med. Wochenschr.*, 1888) and *Einhorn* ("Ueber d. Verhalten der Lymphocyten zu den weissen Blutkörperchen," Inaug.-Diss., Berlin, 1884, ref. *Fortschr. der Med.*, iii.) distinguish among the leucocytes of the normal blood: (1) *small lymphocytes* with deeply staining nuclei of relatively large size, and with little protoplasm; (2) *large lymphocytes* with large nuclei that stain lightly and with abundant protoplasm; (3) *mononuclear transitional forms* with irregular nuclei; (4) *polynuclear neutrophile leucocytes* with polymorphous nuclei or with several nuclei, and containing neutrophile granules (granules which stain with a neutral dye, obtained by mixing acid fuchsin with basic methyl-green), these forming about seventy per cent of all the white cells of the blood, and migrating in purulent inflammations; (5) *eosinophile cells*, whose protoplasm contains numerous granules staining with acid dyes (eosin); (6) *mast-cells* (0.5 per cent of the white cells) having basophile granulation.

*Löwit* distinguishes among the colorless cells of the blood two different forms which he designates leucoblasts and erythroblasts, and which he believes to have a wholly different significance and not to pass over from one form to the other. The leucoblasts are the lymphocytes with chromatin arranged in clumps, which do not undergo mitotic division, but pass over into the polynuclear leucocytes through fragmentation of the nucleus. The erythroblasts are the colorless young forms of the red cells, which divide by mitosis, and are distinguished from the lymphoid cells by their homogeneous character and slight contractility of the protoplasm. The transformation into hæmoglobin-containing cells occurs partly in the blood, and partly in the bone-marrow.

*Flemming* regards *Löwit's* views as incorrect, claiming that the observations of the latter give no evidence of a transformation of colorless erythroblasts into red cells, and that leucocytes which do not become changed into red cells also divide by mitosis. *Neumann* also is unable to agree with *Löwit*.

*Howell* holds that the bone-marrow contains numerous colorless erythroblasts, which change in the marrow into nucleated cells which later through the extrusion of the nucleus are transformed into non-nucleated red blood-cells.

*Petrone* believes that the red blood-cells of the mammals are only apparently non

nucleated, and that it is possible by means of especial methods of fixation and staining to render the nucleus visible. *Negri* has likewise found similar structures in red cells, but does not believe them to be nuclei. *Malassez* believes that the red cells arise from buds of nucleated cells of the marrow. According to *Denys*, with whom *E. H. Ziegler* agrees, the red blood-cells have a peculiar origin; and in birds are formed from the wall of the venous capillaries of the bone-marrow, which have a germinal layer of red blood-cells in the form of a cellular coating of many layers, which give off into the blood-stream cells, which then come to contain hæmoglobin.

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§ 86. The new-formation of transversely striated muscle-fibres takes its start from portions of old muscle-fibres; and although, after injury to a muscle, the intermuscular connective tissue may be excited to active proliferation, there is formed in consequence only connective tissue, or probably also the sarcolemma of new fibres, but never new contractile substance.

The first signs of a formative activity of the muscle-fibres after injury appear in the muscle-nuclei, in that these become elongated and then divide into a varying number of fragments (Steudel, Nauwerck). Even on the second day there may occur mitotic division (Fig. 171, *a*, *b*) of the muscle-nuclei. This form of division seems to be the only way in which multiplication takes place, and under favorable conditions it occurs very actively after the second day.

The behavior of the contractile substance of the muscle differs very markedly according to the nature and extent of the injury. In the case

of traumatic, toxic, and anæmic injuries it suffers a fragmentation into larger and smaller portions, so that the muscle-cells come to lie in spaces of varying size between the detritus of the muscle-fibres. Crushing and tearing can bring about a wide separation of the parts of the contractile substance. The ends of the pieces of muscle-fibres, in such a case, may be conical, oblique, transverse, or torn in an irregular edge, but not infrequently after a short time the ends become split into two or more pointed filaments (Fig. 171, *a*).

The mitotic division of the muscle-nucleus takes place, not only in nuclei that rest upon living fibres (*a*), but also in the muscle-cells lying free in the spaces between the separated muscle-fibres (*b*); and in both places leads to the production of large multinuclear cells, which form multinuclear protoplasmic masses on the ends of the muscle-fibres (*e*, *f*) as well as on the body of the fibres (*c*). Into these masses the trans-



FIG. 171.—Portions of muscle-fibres showing regenerative proliferation, from muscle-wounds of different ages (Flemming's, safranin). *a*, Pointed ends of the split stump of a muscle-fibre, with nuclear division-figures, three days after laceration of the muscle; *b*, proliferated muscle-nuclei transformed into cells rich in protoplasm, one of which is in process of mitotic division; *c*, piece of a muscle-fibre eight days after tying the muscle; *d*, giant-cells, enclosing necrotic pieces of muscle, from a muscle-scar twenty-six days old; *e*, *f*, muscle-fibres ending in protoplasmic masses (muscle-buds), *e*, from a muscle-scar ten days old, *f*, from one twenty-one days old; *g*, dividing muscle-fibres from a muscle-scar forty-three days old.  $\times 315$ .

versely striated muscle-substance passes without a sharp line of demarcation. There occurs, therefore, *at the same time with the multiplication of the nuclei an increase of the sarcoplasm of the muscle-fibres, and this becomes distinctly visible*; it is probable also that muscle-fibrillæ may become changed back into sarcoplasm.

The muscle-cells not connected with living contractile substance become changed into *large epithelioid cells with large nuclei* (*b*). Through continued division of the nucleus these cells become transformed into *multinuclear protoplasmic masses* (*d*); and a scar, consisting of proliferating connective tissue, of from eight to thirty days old, contains such giant-cells which often enclose the remains of old muscle-fibres (*d*) in large numbers.

The new muscle-fibres develop for the chief part from the richly nucleated sarcoplasm, which appears in the continuity and at the ends of the muscle-fibres, in connection with the formation of numerous large nuclei, and which through its increase of size causes an increase in the thickness and length of the muscles, which has been designated *budding* by Neumann.

With the transformation of the sarcoplasm into muscle-fibrillæ there appears gradually a longitudinal and later a transverse striation, a sign that the organic structure of the plasma has completed its development in the way characteristic of muscle.

The greater part of the *proliferating muscle-cells which have no connection* with living muscle-fibres die; but it is to be noted that they persist for a long time, so that not infrequently there may be seen in muscle-scars from eight to forty days old great numbers of protoplasmic masses very rich in nuclei. Under certain circumstances these may form long, connected bands, or rows of separate pieces of protoplasm. There can be no doubt that a part of these cells under favorable conditions become transformed into transversely striated muscle-substance; and this takes place either by the formation of new independent muscle-fibres or by union with old muscle-fibres or muscle-buds. The disconnected new-formation of muscle from proliferating muscle-cells occurs particularly when the contractile substance is destroyed while the sarcolemma remains intact (as in typhoid fever). On the other hand, the formation of buds is observed especially at the ends of fibres which have been divided.

The buds springing from the ends or sides of muscle-fibres may cause a simple elongation of the muscle-fibre, frequently deviating from its original direction (*f*). Often there are seen fibres which have split into two or three parts (*g*), so that the old fibres branch as they pass into the muscle-scar. As far as we know, this splitting of the fibre occurs very early (*a*), before the proliferating muscle-nuclei have formed much sarcoplasm, so that the proliferation appears first in the split portions of the fibre. As a result of such splitting a muscle-scar may come to contain a greater number of muscle-fibres than were originally present in the affected area.

*Hypertrophy of transversely striated muscle* takes place through an enlargement of the individual muscle-fibres; the thin muscle-fibres in particular becoming increased in thickness (Morpurgo). The nuclei do not become increased in number. On the other hand, such an increase does take place in the case of a growth in length of the muscle; and is the result, most probably, of amitotic division (Morpurgo).

A **new-formation of heart-muscle** has not yet been positively demonstrated. After injuries of the heart, division figures appear in the muscle-cells, but after a few days these can no longer be demonstrated, and the wound heals through the formation of ordinary scar-tissue. Focal degenerations of the myocardium likewise heal by connective-tissue cicatrization. If through any reason the **heart-muscle becomes hypertrophied**, the increase in size takes place through the enlargement of the muscle-cells; whether an increase in the number of the cells also occurs is not yet known with certainty.

A **new-formation of smooth muscle-fibres** as well as regeneration, occurs after traumatic or toxic and ischæmic degeneration. It occurs also in hypertrophic new-formations of muscle-tissue—for example, in tumors—and is initiated by mitotic division of the nuclei of the muscle-cells, which is followed by division of the cells. According to the results of experimental work and also of observations upon the muscle-tissues of man, the reproduction of fibres after injuries and focal degenerations is but slight, ceasing after a short period. Thus, for example, defects in the muscularis of the stomach and intestines or of the bladder are, for the chief part, closed only by connective tissue.

**Hypertrophy of smooth muscle-fibre** is a phenomenon which, within

certain limits, is of very frequent occurrence. In the pregnant uterus the size of the muscle-cells may reach five to ten times the ordinary size. Of other organs the bladder most frequently shows a marked hypertrophy of smooth muscle.

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§ 87. **Regenerative new-formation of the nerve-elements of the central nervous system through the new-formation of ganglion-cells** most probably does not occur in man and mammals in post-embryonal life. According to the investigations of Stroebe, on the other hand, *divided nerve-fibrils* (in mammals) *may grow lengthwise to a certain extent*



through sprouting of the axis-cylinder; and this is true particularly of the fibres of the pyramidal tracts and the posterior roots, both of which after being divided grow into the scar-tissue developing at the site of the wound, the former in a downward direction, the latter upward. A complete restoration of nervous tissue does not take place, and a defect in the spinal cord due to trauma is replaced essentially by connective tissue, in part also by neuroglia. It is not yet known whether the loss of single nerve-fibres of the brain and spinal cord may under favorable conditions (preservation of the supporting tissue) be entirely restored through an outgrowth of the axis-cylinders.

**Regenerative and hypertrophic proliferations of neuroglia** are phenomena which occur frequently in diseased conditions of the central nervous system, and either follow degenerative changes of the nervous elements, or in part also destruction of the neuroglia, or they may

appear without such antecedents, in the latter case arising in part during the period of development.

The new-formation is brought about by mitotic division of the nuclei and cell-bodies of the glia-cells, eventually also of the ependyma-cells.

The newly formed glia-cells produce later a great profusion of delicate fibrillar processes (Fig. 172, a), and, as in the normal tissues of the central nervous system, there may be distinguished among these

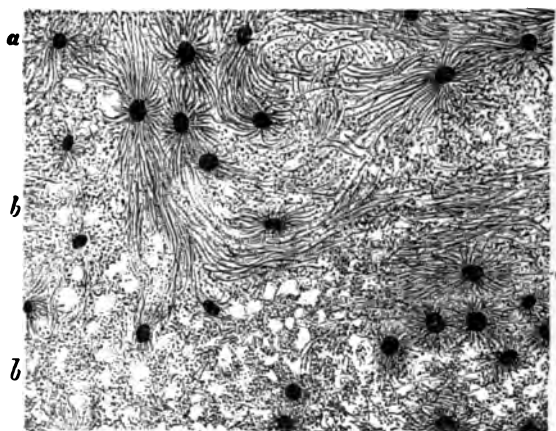


FIG. 172.—Sclerotic tissue from the posterior columns of a case of multiple sclerosis (Müller's fluid, Mallory's method). a, Glia-cells with numerous processes, seen in longitudinal section; b, sclerotic tissue with transversely cut glia fibres.  $\times 500$ .

cells which are known as *astrocytes* (Deiter's cells) two varieties, the so-called "*mossy cells*" (*Kurzstrahler*) and the so-called "*spider-cells*" (*Langstrahler*) with long, stiff, less-freely branching processes (a). The processes of these cells form sometimes a loose, sometimes a dense felt-work of fine fibrillae (a, b) in which the cells, which have but little protoplasm, are embedded. After full development of the tissue a separation of the processes from the cell-bodies may take place. The thickening of the tissue caused by the proliferation is known as *sclerosis*.

**Regenerative new-formation of the nerve-fibres of the peripheral nervous system** is of very frequent occurrence and takes place in all those cases in which through any influence the continuity of a nerve-fibre is entirely or partially interrupted. For its accomplishment, however, it is indeed necessary that the ganglion-cells whose processes form the nerve-fibres in question be preserved.

When a nerve has been severed, the axis-cylinders and medullary sheaths, in the distal portion, undergo degeneration, the latter breaking up into drop-like detritus, which later is dissolved. During the disintegration of the nerve-fibres the nuclei situated beneath the sheath

Schwann undergo mitotic division and form cells rich in protoplasm, which may take up into themselves the products of the destruction of the nerve-fibres.

Of the proximal portion of the nerve the peripheral extremity alone degenerates, as far as the next Ranvier's node, or the next one beyond.

The **regeneration of the nerves** begins a few days after the operation, in the proximal portion, about 0.4-2 cm. above the cut end.

The first change consists in a swelling of individual axis-cylinders in the peripheral parts of the nerve-bundle of the proximal end, which is later followed by a splitting-off of two to five or more new axis-cylinders. The new axis-cylinders arising in this way from the old ones grow in a longitudinal direction (Fig. 173, *a, b*) and form, within the sheath of Schwann, whole bundles (Figs. 173, *c*; 174, *e*) of newly formed nerve-fibres, which for the most part fill up the entire lumen of the old nerve-tubes, and indeed stretch it, and more rarely enclose remains of the old fibres (Fig. 174, *f*). Single fibres may even break through the old sheath of Schwann, and then either extend further in the endoneurium, or penetrate through the perineurium of the nerve-bundle into the epineurium.

In this way there are formed on the lower end of the proximal portion of the nerve a large number of new nerve-fibres, which in the beginning consist only of the newly formed axis-cylinders, but immediately surround themselves with a medullary sheath, which by reason of its irregular development gives to the nerve-fibres a varicose appearance (Fig. 174, *c*). Later the fibres acquire a neurilemma-sheath—that is, a connective-tissue covering which is probably formed from the nerve-corpuscles concerned in the proliferation.

When a nerve is entirely severed and there is no possibility of a union with the distal portion—as, for example, occurs in all amputations of the extremities—there is formed in the region of the cut end an embryonic tissue, springing from the connective tissue of the nerves, which later on becomes changed into connective tissue. In the beginning free from nerves this connective tissue becomes penetrated by young nerves growing out from the



FIG. 173.—Old and newly formed nerve-fibres from an amputation-stump, in longitudinal section (Müller's fluid, Weigert's stain). *a, b*, Old nerve-fibres, from which several young nerve-fibres have grown; *c*, neurilemma with young nerve-fibres.  $\times 180$ .



FIG. 174.—Cross-section of a nerve-bundle of the median nerve just above a wound dividing the nerve, made four months previously (Müller's fluid, carmine). *a*, Perineurium; *b*, endoneurium; *c*, cross-section of a vessel; *d*, old unchanged nerve-fibre; *e*, bundle of newly formed nerve-fibres; *f*, newly formed nerves, with remains of old fibres inside the same sheath.  $\times 200$ .

nerve-fibres of the nerve-stump, which, arranged in small bundles, or scattered, grow into the connective tissue and penetrate it in every direction (Fig. 175). Not infrequently the growth of nerves is so extensive that nodular or clubbed swellings (Fig. 175, *b*) arise on the ends of the nerves. Such a swelling is known as an *amputation-neuroma*.

When a nerve after division is again united, or if the division of the nerve is only partial, the nerve-fibres growing out from the proximal end after penetrating the connective tissue formed in the site of the wound, may in part, or all, find their way into the peripheral portion of the nerve where, in the mean time, the nerve-fibres have been destroyed. In this way the *distal end may again become neurotized*—that is, supplied by new nerves. According to investigations of Forssmann, the direction of the newly growing fibres is governed by chemotactic influences arising from the disintegration-products of the old nerve-fibres.

According to the investigations of Vanlair the growth of a regenerating nerve is about 0.2–1 mm. daily, according to the character of the tissue. A portion of the new nerve-fibres may penetrate into the old, empty sheath of Schwann; others extend into the epineurium and perineurium, and in this situation grow toward the periphery to the end-organ. Single fibres may pass by the end of the nerves, and grow toward the periphery, either along the old nerves or by an independent route. Many fibres, which leave the old route, are finally lost in the tissues. In the lower portion of the intermediate substance (Vanlair) the nerve-strands begin to separate into bundles again, and with the formation of a perineurium about the latter, the regenerated nerve takes on more and more the structure of a normal nerve.

The above-described process of regeneration requires for its accomplishment

weeks or even months, and sometimes is not complete after several months.

The question of the **regeneration of the central nervous system** is still under discussion. It is generally accepted, as having been established beyond all doubt, that in the cold-blooded animals, reptiles, and tailed amphibia, a regenerative new-formation of portions of the central nervous system can take place. In the case of warm-blooded animals, particularly in the mammals, the majority of experimental investigations have failed to demonstrate a regenerative new-formation of ganglion-cells. *Tedeschi*, *Vitzon* and others, claim to have observed, after injuries of various kinds, both a new-formation of neuroglia and of ganglion-cells and nerve-fibres; but the investigations carried out in my laboratory by *Tschistowitch* seem to me to contradict



FIG. 175. -Amputation-neuroma of the sciatic nerve, in longitudinal section (amputation of nerve nine years previously) (Müller's fluid). *a*, Nerve; *b*, neuroma.  $\times 3$ .

these assertions. The results obtained by *Grunert* in experimental work with pigeons agree with the conclusions arrived at by *Tschistowitsch*.

*Monti* and *Fieschi* could demonstrate no evidences of regeneration in the ganglion-cells of the sympathetic after injuries. *Torelli* found only degenerative changes in the ganglion-cells of the intervertebral ganglion after injury of the same.

The new-formation of peripheral nerve-fibres has been made very frequently the subject of experimental research, and different observers have come to very different conclusions (see *Stroede*, *l. c.*). The above-described mode of new-formation I regard as firmly established, in so far as its essentials are concerned, upon the ground of personal investigations. I have been unable to confirm the views of *Neumann*, *Dobbert*, *Duszkiewicz*, *Cattani*, *Weir Mitchell*, *Gluck*, *Beneke*, *von Büngner*, *Wieting*, and others, who hold that the new fibres in the distal portion of the severed nerve rise autochthonously from the nuclei of the sheath of Schwann, or from the old axis-cylinder, or from a protoplasmic mass formed by a chemical transformation of the medullary sheath and axis-cylinders (*Neumann-Dobbert*). Likewise, the attempt made by *Neumann* and *Wieting* (*Marchand*) to bring into accord the established fact of the outgrowth of the axis-cylinders of the proximal portion into the scar uniting the severed ends, with the theory of the origin of new nerve-fibres from the nuclei of the sheath of Schwann, or from the remains of old fibres, or from both, by the assumption that the axis-cylinders growing from the proximal end convey a stimulus from the nerve-centres to the distal portion and thereby make possible the development of new fibres, I regard as unsuccessful, and hold to the above-given view. I am further of the opinion that the medullary sheath is not formed by the cells of the sheath of Schwann, but represents a product of the axis-cylinders; but further investigations as to this point are needed. According to *Nissl*, *Marinesco*, and others (see *Barbacci*, *l. c.*) there occurs, after the severing of a nerve, first a degeneration in the corresponding ganglion-cells with disintegration of the Nissl's bodies, and this may lead to the destruction of individual cells. Later, progressive changes with new-formation of chromatin take place, and may lead to hypertrophy of the cells (*Marinesco*); these changes reach their maximum in about ninety days, after which time there is a return to the normal condition.

The regenerative new-formation of the tissues of the eye has in recent years been repeatedly an object of research. According to *Wolff*, *Müller*, and *Kocha* the lens of tritons may regenerate, after removal, by means of a proliferation of the epithelium of the inner layer of the iris. According to *Röthig*, the same thing occurs in the trout. *Gouin* observed in rabbits, after the lens had been removed in such a manner that the capsule and some of the equatorial lenticular fibres and epithelium of the anterior wall were left behind, that there occurred a proliferation of this epithelium, leading to the union of the anterior and posterior walls through cells resembling connective-tissue cells. A new-formation of lenticular fibres from these cells does not take place. Remains of the lenticular fibres may form a rudimentary, useless lens, which in the case of young animals may become somewhat enlarged through the growth of the fibres. *Randolph* obtained somewhat better results in guinea-pigs. In the human eye similar formations are seen after removal of the lens, and are known under the name of "KrySTALLWULST" (*Baus*). According to *Franke*, *Kröckmann*, and *Stoeber*, the sclera possesses but slight power of proliferation. Wounds of the same are healed chiefly through proliferation of the choroid and episcleral tissue.

According to *Baquis*, there occurs, in the injured retina of the rabbit, division of both ganglion and neuroepithelial cells. According to *Kröckmann*, the pigment-epithelium is capable of extensive regeneration, but neuroepithelium, on the other hand, is not again formed.

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### III. The Results of Transplantation and Implantation of Tissues and Organs.

§ 88. The local regeneration of tissue is, as mentioned in the last part, very often but slight, so that losses of tissue may be followed by permanent defects, and in place of the original structures there may appear only a cicatricial tissue of a lesser value. Consequently, from practical reasons, many attempts have been made, through **transplantation** and **implantation** of tissue, to aid and to improve the healing-process; and such attempts have in part been successful. At the same time they have also thrown light upon the individual life of the tissues and upon the behavior of the organism toward implanted living tissue.

The most successful results have been obtained in the *transplantation of tissues which remain connected with their nutrient vessels*, since the same, at the point of union between the transplanted portion and the underlying tissues upon which it is placed, grow together with the latter in essentially the same manner as do the edges of the wound in the case of a cut. This method is utilized most frequently in the case of plastic operations upon the surface of the body, but it finds application also in internal surgery. For example, wounds of the bladder, intestine, ureters, tubes, etc., may be easily closed through implantation of the omentum; and the surface presenting upon the lumen of the organ concerned becomes very quickly covered over by the neighboring epithelium, which extends over it from the edges, or is also transplanted from the opposite epithelial surface (Cornil, Carnot); while the omentum itself grows to the adjacent wound-surfaces, and thus through changes in its structure completely closes up the defect. Very often such an implantation of the omentum occurs spontaneously, as, for example, in the case of traumatic or ulcerative perforations of the intestine, stomach, gall-bladder, etc., and even large openings may be closed in this manner. As experimental investigations have shown, portions of intestine provided with blood-vessels may be implanted into other portions of the intestines, into the bladder (Enderle), stomach (Reerink), and can heal perfectly in these



locations with preservation of their own epithelium. Likewise, portions of bone or cartilage connected with the periosteum or perichondrium respectively, and with nutrient vessels, may be implanted into neighboring tissue.

**Transplantations of tissues completely freed from their basement-structures** have also been successfully performed, since cells loosened from their connection with the organism are able to preserve their vitality for a certain length of time. The cells of the epidermis are able to live for the longest time; when kept cool they may be preserved alive for several (two to nine) days (Wentscher claims to have been able to preserve epithelium alive for twenty-two days). Ciliated epithelium may also be preserved alive for several days and still show movements of the cilia. Next to the surface-epithelium in this respect stand the connective tissues, while other tissues quickly die, the cells of the brain and kidney most rapidly, dying within a few hours after an obstruction to the blood-supply. According to the investigations which have been made up to the present time (Saltikow and others) the tissues of the skin, periosteum, interarticular cartilages, muscle and cartilage easily preserve their vitality for two to three days. Morpurgo found cells of the periosteum to be capable of reproduction even after seven to eight days. The tissues of the vessels, tendons, and neurilemma appear to be somewhat more resistant. Exact statements with regard to this point cannot be made at present, since, on the one hand, the expiration of life does not take place suddenly, but gradually with the constant diminution of vital cells; and, on the other hand, the conditions under which the excised portions of tissue are preserved also influence the duration of life.

*Transplantations of skin* give the best results, and were first recommended by Reverdin and Thiersch for the healing over of broad, open wounds and have since been extensively used for this purpose. The material used consists of pieces of skin which may be taken either from the same individual or from another person. Ordinarily, strips of skin removed by means of a sharp knife are used, which include the tips of the papillæ and the upper layers of the corium. Epithelium in connection with a thicker layer of the corium may also be successfully transplanted, and in the case of injuries, large portions of the skin which have been completely torn off may be again joined by healing to the deeper tissues on the very same spot from which they had been removed.

The transplantation may be made either upon a fresh wound-surface or upon one already showing proliferation. The strips of skin are held firmly in place by means of moist bands of gauze. The pieces of skin become fastened to the surface of the wound by means of coagulated blood or lymph. In successful cases a firm union with the underlying tissue takes place within about eight days.

The nourishment of the transplanted pieces (Fig. 176, *d*) is obtained first from the tissue-fluids which exude from the underlying tissues. Later, there begins in the latter a vascular connective-tissue proliferation (*b, c*), and the transplanted portion becomes penetrated from below by new blood-vessels (*g*) accompanied by fibroblasts, so that it finally becomes interspersed with new blood-containing vessels and areas of granulation tissue. Under favorable conditions the old vessels may again become opened through the ingrowth of new vessels.

The behavior of the transplanted portion varies in individual cases, the number of cells living and proliferating changing with the condi-

tions. A part of the cells of the transplanted portion is always lost, and this is shown macroscopically in part by the repeated desquamation of the superficial layers of the epithelium (*f*). Other cells, both epithelial and connective-tissue cells, proliferate and produce new tissue.

The final outcome of a successful transplantation is the covering over of the area with transplanted epithelium and in part also by transplanted corium. Through the latter it is made possible that the cicatricial area comes to possess papillæ. To what extent in a given case the superficial layers of the cutis arise from the skin-graft or to what extent from the tissue upon which it is planted, cannot be determined. If the papillary



FIG. 176.—Skin-graft four and one-half days old (formalin, hæmatoxylin, picrofuchsin). *a*, Deep layer of the corium; *b*, proliferating granulation-tissue; *c*, boundary of proliferating zone; *d*, *e*, transplanted portion of skin; *f*, desquamation of the horny layer; *g*, vascular offshoots and granulation-tissue extending into the transplanted connective tissue.  $\times 107$ .

bodies remain preserved, a portion of the tissue may be formed from immigrating fibroblasts. After a time the transplanted area comes to contain nerves which grow into it from the edges, and there is restored first the tactile sense (Stransky), later the sensibility of pain and temperature. New elastic tissue also develops, as in ordinary scars, from the ends of the old fibres.

Besides skin-transplantations, there have been attempted transplantations of almost all the tissues: periosteum, bone-marrow, bone, muscle, nerves, thyroid, pancreas, mammary gland, mucous glands, ovary, testis, etc.; also of tissue-combinations, as, for example, a rat's tail from which the skin has been stripped. Embryonal tissue has also been transplanted

in a variety of ways. Finally the attempt has also been made to transplant tissues from one animal to another of a different species.

Such transplantations have been made upon open wounds, into the subcutaneous tissues, peritoneal cavity, glandular organs and lungs, either by direct operative procedures or by the introduction of the tissue into the blood-stream through the blood-vessels.

The results of all these experiments may be summed up as follows:

*In all transplanted tissues there occurs first a degeneration*, and a part of the tissue dies. After a certain time there usually results a *proliferation* of the remaining portion, which may lead to a new-formation of tissue. Connective-tissue cells form new connective tissue; periosteum and bone-marrow form bone or connective tissue; muscle-cells, new muscle; cartilage, new cartilage; surface epithelium, new epithelium (epithelial cysts). Of the glands the thyroid, mucous glands, and mammary glands may form new glandular tissue, while such a new-formation does not take place in the case of the kidney, liver, testis, and ovary. In the case of the liver only the epithelium of the bile-ducts proliferates. Only in the case of the transplantation of the ovary into the peritoneal cavity of the same animal can the ova ripen and pregnancy occur (Knauer, Ribbert, Gregorieff). The tissues of young individuals in general show a greater capacity for proliferation than those of old people. In the case of the transplantation of complicated tissues, as, for example, the skinned tail of a rat, all the different tissues may produce new tissues and the whole piece grow.

*Embryonal tissue* can likewise grow after transplantation and become differentiated, and it is shown that firm cartilage in particular, which in later life shows but little power of proliferation, is longer preserved and shows further growth, while the delicate soft tissue-formations easily die.

*After a certain time* there occurs in almost all the transplanted tissues, as well as in the newly formed tissue, a *retrograde change*, and they are *finally destroyed through the ingrowth* of tissue from the neighborhood. The time at which this occurs varies with different tissues, and is dependent partly upon the character of the tissue, and partly upon the surrounding conditions. Implanted surface-epithelium can under certain conditions remain permanently, and give rise to *epithelial cysts*. Portions of thyroid, mammary gland, and pancreas are preserved for a long time. Cristiani found pieces of thyroid intact two years after implantation. The majority of the tissues, however, disappear within a few months. In glands which are not capable of proliferation the gland-cells die first. If all of the implanted piece is not destroyed it may become encapsulated.

*Tissue of different species*, when transplanted, does not grow, but is either *destroyed* or *encapsulated*, sometimes quickly, sometimes slowly.

According to the published observations, *the implantation of tissue does not lead to the formation of a permanent tissue* from the transplanted piece except in the case of the transplantation of skin. Nevertheless, such an implantation may, under especial conditions, have a transitory or permanent value. The implantation of thyroid or pancreas tissue may for a certain time check the harmful consequences of the loss of these glands. Through implantation of a tissue into a defect a temporary filling of the latter may be produced, and the neighboring tissues are thus permitted to proliferate for a longer time, and to form a greater amount of new tissue along the framework afforded by the implanted portion, and so finally to close up the defect completely. Bone (not connected with nutrient vessels) when implanted into a portion of the skeleton is destroyed, and

absorbed (equally so in either case, whether living bone or dead and macerated bone is implanted), and is replaced by new bone arising from the neighboring periosteum and bone-marrow. In this way there may be obtained a better healing of the bone-defect, and such implantations of bone or cartilage may also be made use of in the case of other tissues, for the stimulation of a more abundant production of tissue for the purpose of filling up tissue-defects.

The transplantation of nerves has never resulted in the new-formation of a nerve from the transplanted piece. The attraction which the products of disintegration of a nerve (Forssmann) exert upon the axis-cylinders growing into the wound may be utilized to direct the course of the growing nerves into certain channels.

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#### IV. The Metaplasia of Tissues.

§ 89. **Metaplasia** of a tissue is that process by which an *already fully-developed tissue is changed into another tissue* without passing through an intermediate cellular stage—that is, through the stage of an embryonic or formative tissue. Such a transformation occurs only in tissues which are closely related to each other, particularly in the **connective tissues**. All the tissues belonging to this group may, under pathological conditions, be transformed, one into another, without the occurrence of any intermediate proliferation—a phenomenon which in itself is not surprising, as such transformations occur also under normal conditions. Mucous tissue becomes changed to adipose tissue through the conversion of the stellate connective-tissue cells into round fat-cells through the taking-up of fat, while the mucous ground-substance disappears. Lymph-



adenoid tissue after the disappearance of the lymphoid elements may be converted into adipose tissue through the taking-up of fat into the cells of the reticulum.

Through disappearance of the fat, adipose tissue acquires the appearance of mucous tissue, and at times may also contain mucin. If the ground-substance of hyaline cartilage becomes liquefied to form a mucin-containing jelly, or if it becomes completely dissolved, the cartilage-cells thus set free (Fig. 177, *a*) become changed to stellate cells anastomosing with one another (*c, b*), so that a tissue is formed which corresponds in its structure to mucoid tissue or to the reticulum of the bone-marrow. Through the taking up of fat this tissue may become changed into adipose tissue; through the collection of round cells in its meshes it becomes a cellular marrow-tissue. If the basement-substance of hyaline cartilage becomes fibrous, and changes at the same time into a glue-producing sub-



FIG. 177.—Metaplasia of cartilage into reticular tissue, in arthritis fungosa (alcohol, hæmatoxylin). *a*, Hyaline cartilage; *b*, tissue consisting of branched cells; *c*, cartilage-cells, set free by the liquefaction of the basement-substance of the cartilage, and becoming transformed into cells of mucous tissue.  $\times 400$ .

stance, there is formed a fibro-cartilage. If the cartilage-cells lose their characteristic nature and become changed to flat connective-tissue cells, the cartilage becomes changed into ordinary connective tissue.

When portions of cartilage change into marrow tissue (Fig. 178, *a, h, i*), other portions of the same may become converted into osteoid tissue (*f*) and bone, whereby the ground-substance is changed into a glue-producing substance and impregnated with lime-salts, while the cartilage-cells become bone-cells, in the neighborhood of which the basement-substance of the bone forms the serrated bone-corpuscles. If connective tissue becomes directly changed into bone (Fig. 179) there occurs in the first place a thickening of the ground-substance (*b*), and later a deposit of lime-salts (*c*), whereby the connective-tissue cells (*d*) come to lie in serrated spaces and are changed to bone-cells (*d*).

In the transformation of connective tissue into mucous tissue, the fibrillæ disappear, and there appears in their place a gelatinous mucus. Should numerous lymphoid round-cells collect in a fibrillar connective tissue, and if at the same time there occurs a loosening or disappearance of the connective-tissue fibres while the connective-tissue cells persist



and unite, through the formation of processes, to form a reticular tissue, there may be developed a lymphadenoid tissue.

The metaplasia of connective tissue is to be distinguished both from simple degeneration and also from processes of growth. From the

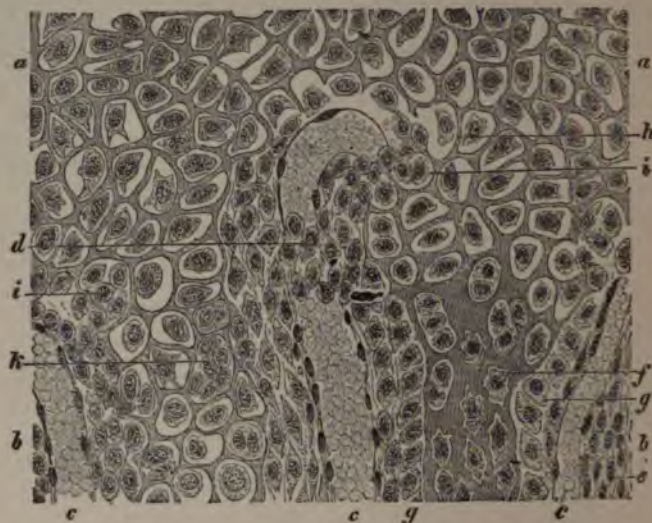


FIG. 178.—Formation of bone from cartilage, in a callus fourteen days old (Müller's fluid, picric acid, hematoxylin, carmine). *a*, Hyaline cartilage; *b*, marrow-spaces; *c*, blood-vessel; *d*, cellular marrow; *e*, fibrous ground-substance; *f*, osteoid tissue; *g*, osteoblasts; *h*, cartilage-cells freed through the disappearance of the capsule; *i*, proliferating cartilage-cells in opened capsule; *k*, proliferating cartilage-cells in closed capsule.  $\times 200$ .

former no new tissue arises, but the old one dies; in the latter there arises through cell-division a new tissue rich in cells. Metaplasia stands, in a certain sense, midway between these processes. It gives rise to a new tissue, but cell-proliferation is either wholly absent or plays but a small part.

In many ways the process is allied to the retrograde changes; thus, for example, the metaplasia into mucous tissue is a process closely related to mucous degeneration. The newly formed tissue, moreover, is not infrequently transitory. On the other hand, proliferation-processes

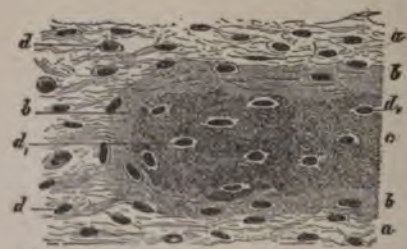


FIG. 179.—Formation of bone from connective tissue (alcohol, hematoxylin). Cross-section through a bone trabecula in process of formation; from an ossifying fibroma of the periosteum of the upper jaw. *a*, Connective tissue; *b*, thickened tissue, forming the groundwork of the new bone; *c*, deposits of lime-salts; *d*, connective-tissue cells; *d*<sub>1</sub>, bone-cells.  $\times 180$ .

are very frequently seen following metaplasia, thus showing another relationship to the progressive disturbances of nutrition. Further, such metaplastic processes occur frequently in association with proliferation, especially the new-formation of bone, since in this case an already characteristic, developed tissue (Fig. 178) passes over into another tissue.

Metaplasia of epithelium occurs most frequently in mucous membranes showing chronic inflammatory processes, as, for example, in the mucosa of uterus, urethra (gon-

orrhœa), nose (ozæna), and of the trachea, whereby the cylindrical epithelium becomes changed into flattened.

This transformation takes place through a change in the character of the regenerating epithelium as the result of repeated loss of the original epithelium. In the stratified squamous epithelium of a mucous membrane there may occur also a *cornification* of the uppermost layers of cells, both in regions where squamous epithelium is normally present, and also in regions which normally possess none, as, for example, in the ureters, as well as in places where it has been formed pathologically, as in the nose and uterus.

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## CHAPTER VII.

### Inflammation.

#### I. The Early Stages of Acute Inflammation.

§ 90. Under the designation **inflammation** are grouped those pathological phenomena which represent a **combination of different pathological processes**, consisting on the one hand of **tissue-degenerations** and **tissue-proliferations**, and on the other of **pathological exudations from the blood-vessels**. *Degenerations of tissue and pathological exudations initiate the process; with these tissue-proliferation is sooner or later associated, the latter leading in the further course of the process to a compensation for the disturbance—that is, to healing.* The *proliferation of tissue* may, therefore, be regarded as *regenerative*, but such new-formation of tissue may be in excess of that which is useful to the body. The tissue-degenerations and proliferative processes described in the previous chapters appear for the greater part as participating factors in inflammation; the process acquiring its inflammatory character through the combination of tissue-degenerations and tissue-proliferations with pathological exudations.

*Deeper tissue-lesions—that is, injury of tissues containing blood-vessels—which in some way or other affect the vascular system, will, therefore, constantly bear at some time during their course the character of an inflammation. The formation of scar tissue, the healing of transplanted tissues, as briefly described in the last chapter, always take place through processes essentially inflammatory in nature.*

**Exudation in acute inflammation** is constantly associated with a pronounced *hyperæmia*, which appears even before the beginning of the exudation, and hence ushers in the latter. As a result of the combination of hyperæmia and exudation the inflamed tissue becomes reddened and swollen. When situated on the surface of the body, where a cooling of the tissues takes place, the increased flow of warm blood from the deeper tissues causes a local increase of temperature. If the tissue affected contains sensory nerves, the sensation of pain will be produced as the result of the changed conditions in the inflamed area.

**Redness, swelling, increased warmth, and painfulness of the inflamed tissue** are phenomena which even in ancient times were regarded by physicians as the signs of inflammation; and **rubor, tumor, calor, and dolor** were designated by Celsus, at the beginning of our era, as the **cardinal symptoms of inflammation**. To these four was then added still a further symptom, **functio læsa, altered function** of the inflamed tissue.

The **causes of inflammation** may lie either in *mechanical, thermal, electrical, or chemical* influences, as well as in the *influence of parasites*. The common characteristic of all these injurious agencies is the *production, in the first place, of a local tissue-degeneration, which, when of a certain extent and intensity, is associated with disturbances of the circulation and of the vascular secretion.* The causes of inflammation are not specific; any

injurious agent may excite inflammation if on the one hand its action is sufficiently intense to cause certain disturbances of circulation in association with tissue-degenerations, but on the other hand not so intense as completely to destroy the tissue and stop the circulation.

The great majority of the causes of inflammation reach the human organism from the outside, but excitants of inflammation may be formed also within the body. In the first place bacteria which have penetrated into the tissues very often form within their protoplasm or from substances present in the body certain products which are capable of exciting inflammation. Moreover, substances that excite inflammation may arise within the organism without the aid of parasites; particularly as the result of the death of large masses of tissue from any cause, as, for example, as the result of anæmia, or when as the result of disturbances of metabolic processes (gout) products of metabolism are deposited in the tissues.

The causes of inflammation may act upon the tissues either from the portions of the body accessible from without, or from the lymph and the blood; and we may, therefore, distinguish **ectogenous, lymphogenous, and hæmatogenous inflammations**. Through the spread of an inflammation to neighboring tissues there arises an **inflammation by continuity**; as the result of the transportation through the lymph or blood stream of an agent causing inflammation, there are produced **metastatic inflammations**. If injurious substances are discharged through the excretory organs, **excretory inflammations** may arise.

When a local injury to tissues has reached such a degree as to produce the exudation characteristic of an inflammation, there is usually found in the first place a **congestive hyperæmia**, as a result of which the blood flows through the dilated blood-channels with increased velocity. After a short time there is a lessening of the speed of the circulation which leads finally to an abnormal **slowing of the blood-current**.

The first **disturbances of circulation**, which find expression in the congestive hyperæmia, may be due either to a stimulation or paralysis of the vasomotor system or to a direct action upon the vessel-walls, particularly upon the arterial walls, leading to a dilatation of the lumen. Although these disturbances very frequently precede the inflammatory exudation, they do not form an essential characteristic of inflammation, and occur very often without being followed by an inflammatory exudation. Further, they may be absent during the course of an inflammation. The circulatory disturbances characteristic of inflammation are shown only when the **slowing of the blood-current and the pathological exudation from the blood-vessels** set in. The slowing of the blood-stream in the dilated channels and the pathological exudation are dependent upon a *change in structure*, an **alteration of the vascular walls**, through which there results a lasting dilatation of the vessel and an adhesion of the blood to the vessel-wall, causing an *increase of friction-resistance* and an *increased permeability* of the vessel-wall. In the capillaries the persistent dilatation is in great part the result of *relaxation of the connective tissue surrounding the capillaries*, inasmuch as the thinness of the capillary walls makes this tissue bear the greater part of the blood-pressure resting upon them.

The **tissue-lesion** which leads to the phenomena of inflammatory disturbances of circulation and exudation usually affects all parts of the tissue, but under certain conditions may be limited to the vessel-wall, particularly in the case of a hæmatogenous inflammation, in which the

injurious agent acts from the blood. However, the tissue in the region adjoining the capillary walls must soon become involved in association. The tissue-changes brought about by the excitants of inflammation are sometimes only slight, and even on microscopical examination are either not recognizable at all or only with difficulty; at other times they are more severe, so that they may be easily recognized even on macroscopic examination. The latter is particularly the case when some time has elapsed after the action of the injurious agent. During the further course of the inflammatory process there are often added to the lesions produced directly by the causes of inflammation other tissue-changes, which are brought about by the inflammatory disturbances of circulation and the collection of exudate in the tissues.

If in any tissue the cause of inflammation has led to that alteration of the vessels which is the requisite antecedent of an inflammatory disturbance of the secretion of the vessels, i.e., the formation of an inflammatory exudate, and if as a result of this there is already evident a slowing of the blood-stream, the capillary circulation becomes irregular, and there occurs here and there either stagnation or a permanent or transitory stasis. Since in this event the white blood-corpuscles often remain clinging to the vessel-walls while the red blood-cells are carried on, there arises **in the capillaries a more or less marked increase of white blood-corpuscles** as compared to the red. **In the veins**, in which there can be distinguished in the normal circulation an axial red stream and a peripheral plasma-zone free from cells, a greater or less number of **leucocytes pass over into the peripheral plasma-zone**, when the slowing of the circulation has reached a certain degree. A still greater slowing of the current leads to the passing over of blood-plates and red blood-cells into the peripheral plasma-zone, and finally the difference between the axial-stream and the peripheral zone may be entirely lost.

When leucocytes pass over into the peripheral zone they either roll along in the same or cling to the wall of the vein, either to roll on again after a time or to remain permanently attached. If this occurrence leads to a marked accumulation of leucocytes along the vein-walls, the condition is known as the **marginal disposition of the white corpuscles** (Fig. 180, *d*).

Following the accumulation of the leucocytes in the capillaries and the marginal disposition in the veins there occurs later an *emigration of the leucocytes* (Fig. 180, *d*, *c*) from the vessels involved, and at the same time a *pouring-out of fluid from the vessels into the tissues*.

The **emigration of the white corpuscles** is an active process, which is accomplished through the amœboid movement of the cells, and to a certain extent occurs under normal conditions. The cause of the marked emigration seen in inflammations is doubtless a change in the vessel-walls, which favors the clinging of the cells to the walls and their passage through the latter. According to investigations by Arnold, Thoma, and others, the leucocytes pass out through the lines of cement-substance between the endothelial cells; and in the alteration of the vessel-wall due to inflammation localized defects occur in the wall as the result of the widening of these lines. The emigration is accomplished by the leucocytes first sending a process through the vessel-wall, the remainder of the cell-body then flowing after the process, until finally the entire cell-body is outside of the vessel. Arrived here the leucocytes first remain lying in the immediate neighborhood of the point of diapedesis, but often wander farther, the direction of the wandering being determined

partly by *mechanical stimuli*, partly by *chemotaxis*—that is, the repelling or attracting influences exerted by chemical substances present in solution in the tissue-juices. Possibly chemotactic influences sometimes exert an action even upon the leucocytes in the capillaries or those in the peripheral zone of the veins. The leucocytes emigrating from the vessels are chiefly polynuclear forms, which constitute about seventy per cent. of the white blood-corpuscles in the blood. The number of the migrating cells is sometimes large, sometimes small.

The **pouring-out of the fluid exudate**, whose composition always differs more or less from that of the normal tissue-lymph, and which is characterized by a *relatively high albumin-content*, is a process which is

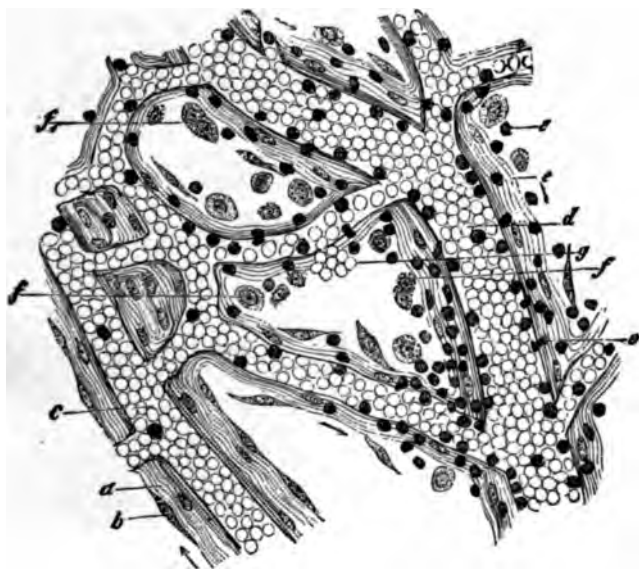


FIG. 180.—Inflamed human mesentery (osmic-acid preparation). *a*, Normal trabecula; *b*, normal epithelium (endothelium); *c*, small artery; *d*, vein with leucocytes arranged peripherally; *e*, white blood-cells, which have emigrated or are emigrating; *f*, desquamating endothelium; *f*<sub>1</sub>, multinuclear cells; *g*, extravasated red blood-cells.  $\times 180$ .

also to be referred to an *alteration of the vessel-wall*, in consequence of which the *secretory function of the latter suffers a disturbance*. It takes place at the same time with the emigration of the leucocytes, but may begin before this event, and may occur also in cases in which the emigration of the leucocytes does not take place at all, or remains within very narrow limits. The *composition of the exudate* is dependent, in all cases, partly upon the especial property of the affected vessels, which always varies according to the tissue-formation to which the vessels belong, and partly upon the degree of vascular alteration; and it may be assumed that the albumin-content is the higher the greater the damage to the vessel-walls. If the extravasated fluid contains fibrinogenic substances and fibrin-ferment, and if, on the other hand, no influences opposed to such a change are acting, **coagulation**—that is, a **separation of fibrin**—takes place.

If the alteration of the vessels is of a very high degree, or if at the same time there is a marked stasis, **red blood-cells may also pass out of the vessels** (Fig. 180, *g*) along with the fluid, either by rhexis or dia-



pedesis. According to Thoma and Engelmann the diapedesis occurs particularly in those places where leucocytes have previously passed through the vessel-wall, and the escape of red blood-cells may follow very quickly by the same route. Since the red blood-cells are not motile, their escape must be regarded as a passive process performed under the influence of the pressure within the capillaries.

The escape of blood-plates into the exudate may take place both in exudates rich in cells and those containing but few, but occurs particularly in exudates characterized by a rich content in fibrin and red blood-cells.

**Tissue-proliferation**—that is, the division of cells and nuclei—is first recognizable about eight hours after the action of the injurious agent; and in many cases appears much later. There are present, therefore, in case the inflammation does not arise in a tissue already in a state of proliferation, the characteristic appearances of inflammatory exudation, and with it also the tissue-degeneration, long before the proliferation begins.

The clinical significance of the term *inflammation* (*inflammatio*, *phlogosis*) has changed but little in the course of time, since the cardinal symptoms of inflammation set forth by Celsus, and accepted by Galen, are recognized as such at the present day. Nevertheless, the views regarding the differentiation of the essential from the unessential in the symptom-complex of inflammation and the accurate determination of the true nature of the process have differed greatly. A comparison of the expressions concerning these points made by the more modern writers (*Virchow*, *von Recklinghausen*, *Cohnheim*, *Ponfick*, *Samuel*, *Thoma*, *Neumann*, *Stricker*, *Heitzmann*, *Gravitz*, *Leber*, *Metchnikoff*, and others) shows that no single writer defines inflammation in the same way as any other, or interprets in exactly the same way any one of the individual phenomena of inflammation. *Ponfick* designates as the cause of inflammation the disturbance of equilibrium in the tissues, "but hesitates to designate retrogressive changes as an indispensable attribute of the inflammatory process, and doubts wholly that they should be regarded as the point of departure and the chief feature of the process." I am of the opinion that "a disturbance of the tissue-equilibrium" is nothing more than a degenerative change of tissue, and regard *Ponfick's* statement, though directed against my definition, as harmonizing with my views. Moreover, I once again emphasize the fact that the alteration of the vessels is a necessary requisite for exudation, and that this alteration is nothing else than a tissue-degeneration.

It was formerly believed that hyperemia was the essential symptom of inflammation. *Rokitansky* held that every inflammation was characterized by a dilatation of the capillaries, slowing of the blood-stream, and by stasis, which was caused by a thickening of the blood through the effusion of serum and the adhesion of the red blood-cells to one another. *Heule*, *Stilling*, and *Rokitansky* attributed the dilatation of the vessels and the slowing of the circulation to a paralysis of the nerves of the vessels, the cause of which, according to *Heule* and *Rokitansky*, is an increased stimulation of the sensory nerves; while according to *Stilling*, the cause lies in a paralysis of the nerves due to the inflammatory irritant. *Eisenmann*, *Heine*, and *Brücke* sought to attribute the circulatory disturbances to a primary spasm of the vessels brought about by the irritation of sensory nerves, which produces behind the contracted portions of the vessels a slowing of the current, irregular circulation, and finally also stasis. *Vogel*, *Emmert*, *Paget*, and others, on the other hand, attributed the dilatation of the vessels and the stasis to an abnormal attraction of the blood by the tissues. Against these views it must be maintained that all the disturbances of circulation produced by contraction or dilatation of the vessels, indeed, introduce or accompany the inflammatory disturbances of circulation, i.e., those leading to exudation, and may exert a modifying influence upon the course of the inflammation, but do not form an essential part of the process, and may be entirely wanting, or may appear without the accompaniment of an inflammatory exudate.

*Rokitansky* sought to explain the pouring out of fluid from the vessels in inflammation by the assumption that with the dilatation of the vessels the walls of the latter became thinned and more permeable. *Vogel*, *C. Emmert*, and *Paget*, on the other hand, made this phenomenon also dependent upon an increased attraction between the blood and the tissue parenchyma or juices. *Virchow*, however (1854), believed that part of the exudate, and indeed that which collected in the tissue-spaces and is poured out upon the free surfaces of the body, to be the result of mechanical pressure in the vessels, i.e.,

pressed-out blood-serum; while a part, which is chiefly taken up by the "irritated" cells, is to be regarded as a product of an increased drawing of the blood-elements through the tissues, as a kind of nutritive educt. Of the cells collecting in the inflamed area, he believed that all originate from a proliferation of the tissue-cells occurring as the result of the action of the inflammatory irritant.

The recognition that the formation of the exudate is to be referred to an injury of the vessel-walls we owe chiefly to *Cohnheim*, whose investigations along various lines were completed by *Samuel*, *Arnold*, *Thoma*, *Binz*, and others. *Cohnheim* also showed that in inflammation the colorless corpuscles emigrate, and form an essential constituent of the inflammatory exudate.

*Dutrochet* ("Rech. anatomiques et physiologiques sur la structure interne des animaux et des végétaux et sur leur motilité," Paris, 1842, p. 214) and *Waller* (*Philosoph. Magaz.*, xxix., 1846, pp. 271, 398) had as early as the years 1842 and 1846 already described the escape of colorless corpuscles from the blood-vessels. These observations had, however, fallen completely into oblivion until *Cohnheim*, in 1867, rediscovered the phenomenon.

According to researches of *Schklarewsky* (*Pflüger's Arch.*, Bd. i.), the peripheral disposition of the leucocytes in the veins is purely a physical phenomenon. If fluids, in which are suspended finely powdered substances of different specific gravity, are made to flow through tubes, it will be found that at a certain degree of retardation of the current, the bodies of lighter specific gravity pass over into the peripheral zone, and at a more marked retardation the heavier bodies also enter this zone.

For the occurrence of the emigration of the white corpuscles, it is necessary, according to the researches of *Binz*, *Thoma*, and *Lavdowsky*, that they be capable of motion and of adhering to the vessel-wall. According to these observers, the emigration of the white blood-cells is not a purely passive, but is in part at least an active process. If the amoeboid power of the white cells be lessened by means of irrigation of the mesentery with a 1.5-per-cent. solution of salt (*Thoma*), or if the vital energy of these cells be lowered by means of quinine or iodoform (*Binz*, *Appert*, *Kerner*), there results an inhibition of emigration. On the other hand, *Pekelharing* believes that quinine, oil of eucalyptus, and salicylic acid cause a contraction of the veins, lessen the permeability of their walls, and thereby hinder the passing-out of the white cells. This view is rejected, however, by *Disselhorst*, who observed a dilatation of the veins after irrigation of the tissues with quinine, carbolic acid, salicylic acid, and mercuric chloride. As there occurs in this case a retardation of the current after a transitory acceleration, without an emigration of the leucocytes collected in the peripheral zone; and as, on the other hand, leucocytes from blood-vessels that have been irrigated for an hour with quinine still retain complete vitality (*Eberth*), *Disselhorst* is of the opinion that the drugs mentioned so change the inflamed vessel-wall that an adhesion of the leucocytes rolling along the wall either cannot occur at all or only with difficulty.

It is very probable that a lesion of the vessel-wall is not absolutely necessary for the emigration of leucocytes (*Thoma*). Since vasomotor disturbances of the circulation can produce migration (*von Recklinghausen*, *Thoma*), it is probable that all of the conditions necessary for this process are furnished by a slowing of the blood-stream with peripheral disposition of the colorless corpuscles and the ability of the leucocytes to perform amoeboid movements and to adhere to the vessel-walls. It is possible that differences in the water-content of the tissues (*Thoma*) also exert some influence, since an increased amount of water causes increased amoeboid movement. It is also possible that the presence, in the tissue-fluids, of substances having active chemotactic properties may cause emigration of those leucocytes in the peripheral zone which are adherent to the vessel-wall.

According to the investigations of *Arnold*, *Thoma*, and *Engelmann*, there is present between the edges of the endothelial cells a soft cement-substance which suffers a change in the circulatory disturbance associated with cell-migration. This change may sometimes, but not always (*Löwit*), be recognized, on histological examination, in the form of numerous circumscribed widenings of these intercellular areas (*Engelmann*). If leucocytes pass through these places in great numbers the cement-substance becomes still more permeable, and may then permit red cells also to pass through in rapid succession (*Thoma*).

Wandering cells are found normally in many tissues (*von Recklinghausen*), and wander from these partly into the lymph-vessels (*Hering*, *Thoma*), and under certain conditions also into the blood-vessels (*Bubnoff*, *Schulin*, *Rancier*, *Senftleben*), or onto the surface of the mucous membranes, where they penetrate between the epithelial cells. They are found constantly in large numbers about the nodes of lymphadenoid tissue in the mucous membranes, and wander from these through the epithelium onto the surface. According to observations by *Kunkel* and *Siebel*, small numbers also reach the free surface of the alveoli of the lungs.

The inflammatory disturbances of circulation and the formation of exudates may be most easily followed in the transparent membranes of cold-blooded animals, particularly in the mesentery, or the extended tongue or the spread-out web of the frog. In the frog's mesentery, which has been spread out on a suitable glass plate, circulatory disturbances and inflammation develop simply through exposure to the air and the resulting evaporation: in the case of the tongue and web, it is necessary to cauterize in order to produce an inflammation. By the employment of suitable apparatus the circulation of the blood and the formation of the inflammatory exudate may also be observed under the microscope in the thin membranes of mammals (mesentery of rabbit, wing-membrane of bat), and observations thus made harmonize wholly with those made upon the frog.

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- See also §§ 91-94.

§ 91. The *cellular and fluid exudates* secreted by the vessels collect first in the immediate neighborhood of the vessels (Fig. 180), but soon spread out in the vicinity, mass themselves in the *lymph-spaces* of the tissue, and thus form a *tissue-infiltrate* (Figs. 181, *c*; 182, *b*; 185, *p*). When the exudate is very abundant it may spread into and infiltrate the neighboring sound tissue that has not been injured by the inflammatory irritant. This *infiltration* may be so marked that new disturbances of circulation and nutrition may be produced, and the *area of tissue-degeneration and inflammatory exudation becomes increased in extent*.

The exudate present in a tissue may be in part absorbed by the tissue-

elements, so that they become swollen, separated from their surroundings (Fig. 181, *c, d*), and not rarely contain *drops of fluid* (*d*) which are com-



FIG. 181.—Recent purulent meningitis (Müller's fluid, hæmatoxylin). *a*, Arachnoid; *b*, subarachnoidal tissue; *c, d*, desquamated endothelium; *c*, pus-corpuses.  $\times 300$ .

monly designated *vacuoles*. There often occurs also a complete **dissolution of the tissue-elements** in the exudate, especially of the connective-tissue cells (Fig. 183, *d, f*), and not infrequently, also, of the intercellular

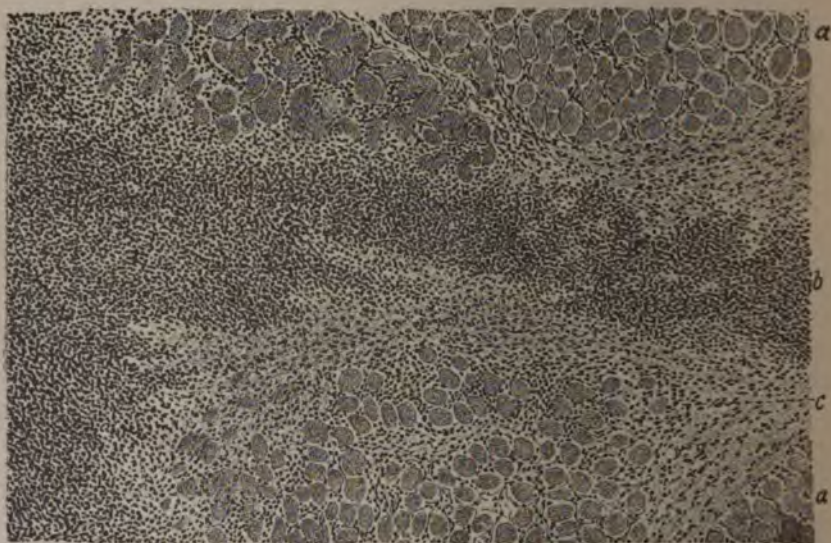


FIG. 182.—Haematogenous staphylococcus myositis (alcohol, hæmatoxylin-eosin). *a*, Transversely cut muscle-bundles; *b*, purulent, *c*, seropurulent, partly coagulated exudate.  $\times 45$ .

substance. In this way both brain and muscle tissue, as well as ordinary connective tissue, may become completely liquefied in the course of inflammation.

If dead cells become saturated with lymph containing fibrinogen, and if fibrin-ferment is formed, the liquefaction of the infiltrated tissue may



be preceded by a **coagulation**, whereby the cells become changed partly into homogeneous masses without nuclei, and partly into granular and fibrillar masses.



FIG. 183.—Section through the border of a blister caused by a burn (alcohol, carmine). *a*, Horny layer; *b*, rete Malpighii; *c*, normal papillae; *d*, swollen cells, some of whose nuclei are still visible though pale, while others have been destroyed; *e*, interpapillary epithelial cells, the deeper ones intact, those of the upper layers are drawn out longitudinally and in part are swollen and have lost their nuclei; *f*, total liquefaction of the cells; *g*, interpapillary cells, without nuclei, swollen and raised from the cutis; *h*, total degeneration of interpapillary cells which have been raised from the cutis; *i*, coagulated exudate (fibrin) lying beneath the uplifted epithelium; *j*, flattened papillae infiltrated with cells.  $\times 150$ .

If the exudate within an organ—for example, in a muscle—lies chiefly in the supporting tissue, while the specific parenchyma appears but little

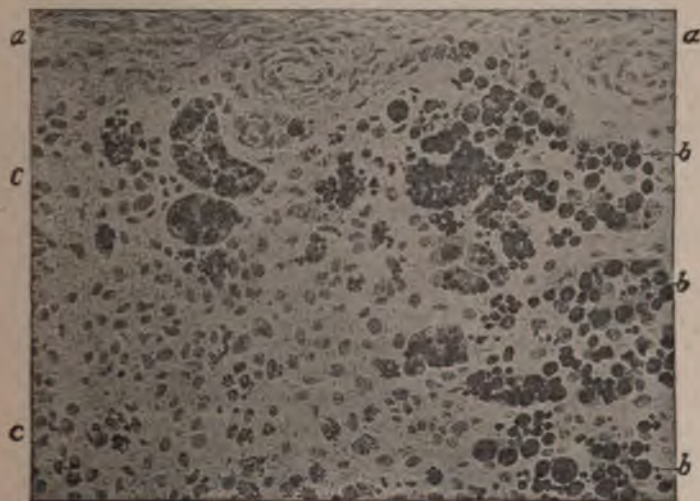


FIG. 184.—Parenchymatous hepatitis (Flemming's solution, safranin). *a*, Liver-capsule; *b*, liver-rods showing fatty degeneration; *c*, liver-cells showing total degeneration.  $\times 300$ .

changed, the inflammation is designated as an **interstitial inflammation** (Fig. 182, *b*). If, on the other hand, the degeneration of the specific



tissue—i.e., the epithelium of the kidney tubules, the liver-cells (Fig. 184, *b, c*), or the contractile substance of the muscles—is the most prominent feature of the process, and if these parts appear saturated with exudate, the condition is called a **parenchymatous inflammation**.

When the seat of an inflammation is on the surface of an organ, it is termed a **superficial inflammation** (Fig. 185). If the exudate gains free access to the surface and flows from the same mixed with desquamated portions of the tissue (Fig. 185, *d, e, f, f<sub>1</sub>, g, h*), the inflammation is called a catarrh. If the pouring out of a fluid exudate on the surface of the skin or mucous membrane is hindered by a coherent horny epithelial layer (Fig. 183, *a*), and if beneath this covering there are formed circumscribed collections of fluid, in which the deeper and softer layers of



Fig. 185.—Mucous catarrh of a bronchus (Müller's fluid, aniline-brown). *a*, Ciliated epithelium; *a<sub>1</sub>*, deeper cell-layers; *b*, goblet-cells; *c*, cells showing marked mucous degeneration; *c<sub>1</sub>*, mucoid cells with mucoid nuclei; *d*, desquamated mucoid cells; *e*, desquamated ciliated cells; *f*, layers of drops of mucus; *f<sub>1</sub>*, layer consisting of thready mucus and pus-corpuscles; *g*, duct of mucous gland filled with mucus and cells; *h*, desquamated epithelium of the excretory duct; *i*, intact epithelium of the duct; *k*, swollen hyaline basement-membrane; *l*, connective tissue of the mucosa, infiltrated with cells in part; *m*, dilated blood-vessels; *n*, mucous gland filled with mucus; *n<sub>1</sub>*, lobule of mucous gland without mucus; *o*, wandering cells in epithelium; *p*, cellular infiltration of the connective tissue of the mucous glands.  $\times 110$ .

the epithelium dissolve (Fig. 183, *d, f, g, h*), the lesions thus produced are called **vesicles** and **blisters**. When the exudate from serous surfaces collects in the body cavities, there are formed in the latter **inflammatory effusions**, which not rarely reach a very large size, distend the affected cavity, and compress the organs contained within it.

It is customary to express the occurrence of an inflammation of an organ by adding the termination "*itis*" to the Greek name of the organ. Thus, for example, are formed the terms endocarditis, myocarditis, pericarditis, pleuritis, peritonitis, encephalitis, pharyngitis, keratitis, orchitis, oöphoritis, colpitis, metritis, hepatitis, nephritis, amygdalitis, glositis, and gastritis. The ending "*itis*" is also sometimes affixed to the Latin names, as, for example, conjunctivitis, tonsillitis, and vaginitis. To denote an inflammation of the serous covering of an organ or of the

tissues immediately about it the prefixes "peri" and "para" are placed before the Greek names with the termination "itis." Thus, for example, are formed the words perimetritis, parametritis, periproctitis, perityphlitis, paranephritis, and perihepatitis.

For certain forms of inflammation especial names are used, as, for example, inflammation of the lungs is called pneumonia, and inflammation of the palate and tonsils, angina.

Since *Cohnheim* taught that the migration of leucocytes *en masse* is an important feature of inflammation and serves as a source for the cells in the exudate, the question of the origin of the cells present in the exudate of acute inflammations has been many times the subject of discussion. While some have regarded all the cells in the exudate as extravasated leucocytes, others have held that the leucocytes arising from the blood-stream form only an unessential element, and that the main part of the cells in the exudate have arisen on the spot from the tissue "irritated" by the cause of the inflammation.

*Stricker* held the opinion that the swelling and hardening of the tissues in inflammation are not caused by the collection of exudate, but by the swelling of the cell-reticulum which was thought to traverse the tissues; and that these changes represent a phenomenon of growth of the cells and their processes which is characterized by swelling. The cellular exudate—that is, pus—he accounts for partly through the segmentation and division of the cell-reticulum swollen by the inflammation, and partly through a transformation of connective-tissue fibrillæ into pus-corpuscles. *Heitzmann* regarded the inflammatory tissue-changes as a reversion of the tissue to the embryonal condition, and believed that the living material is not contained in the cells alone, but infiltrates the entire ground-substance, and increases, in the progress of an inflammation, with the liquefaction of the ground-substance. Connective-tissue cartilage and bone become resolved during inflammation into those elements from which they are formed—i.e., into cells—which then immediately reproduce their kind. *Gravitz* believes that both the cellular infiltrate and pus are formed without any participation of the leucocytes worth mentioning. Everywhere in the tissue, according to his view, there lie concealed in great numbers cells, which he designates slumber-cells, and which are not affected by our nuclear stains and therefore not recognizable (according to him, only from five to ten per cent. of the tissue-cells are known to us); these cells awake in inflammation, and again come into sight—that is, increase in size, stain with nuclear stains, and therefore again become recognizable.

According to the results of an unprejudiced and careful examination of inflamed tissues, there can be no doubt that the description of the origin of the inflammatory infiltrate given by *Stricker*, *Heitzmann*, *Gravitz*, and their pupils, does not correspond to the conditions as they actually exist. The cells which lie in recently inflamed tissue consist in part of leucocytes which have wandered from the vessels and in part of tissue-cells which are more or less degenerated, and are often separated from the underlying tissues. Later, to these there are added newly formed cells which have arisen through the division of pre existing tissue-cells.

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See also §§ 90 and 93.



FIG. 186.—Purulent desquamative catarrh of the trachea in measles (alcohol, hematoxylin, eosin). *a*, Layer of pus-corporcles and desquamated epithelium; *b*, intact deepest layer of epithelium; *c*, basement-membrane; *d*, hyperemic and infiltrated connective tissue of the mucosa; *e*, infiltrated submucosa with mucous glands.  $\times 100$ .

§ 92. Both the *local tissue-degeneration* and the *exudation* may *vary greatly* in different cases, and there may be distinguished accordingly different **forms of inflammation**.

If the exudate consists essentially of fluid, while the cellular constituents are insignificant, it is called a **serous exudate**. When contained within a tissue—for example, within the skin and subcutaneous tissue, or in the lungs—there results an **inflammatory œdema**. The escape of the fluid on the free surface of a mucous or serous membrane gives the picture of a **serous catarrh**; circumscribed collections of fluid beneath the

horny layer of the epidermis with the liquefaction of the soft layers of epithelium lead to the formation of **vesicles** and **blisters** with clear contents (Fig. 183, *d, f*).

When the exudation of fluid on the surface of a mucous membrane is associated with a marked mucoid degeneration of the superficial epithelium (Fig. 185, *b, c, c<sub>1</sub>*), and of the mucous glands (*n*), there arises a

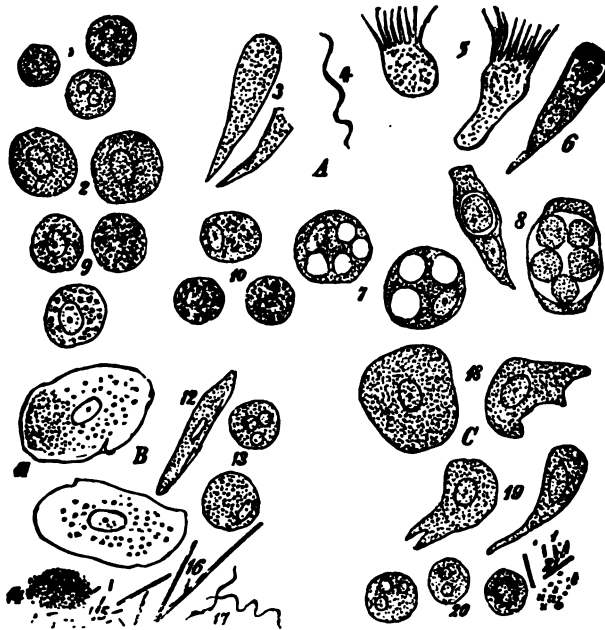


FIG. 187.—Catarrhal secretion of different mucous membranes. *A*, Secretion from mucous membranes with columnar cells; *B*, from the mouth; *C*, from the bladder. 1, Round cells (pus-cells); 2, large round cells with bright nuclei, from the nose; 3, mucoid columnar cells from the nose; 4, spirillum from the nose; 5, mucoid cells with cilia, from the nose; 6, goblet-cells from the trachea; 7, round-cells with spherules of mucus from the nose; 8, epithelial cells containing pus-corpuscles, from the nose; 9, fatty cells; 10, cells containing coal-pigment, from the sputum; 11 and 12, squamous epithelium from the mouth; 13, mucoid pus-corpuscles; 14, micrococci; 15, bacteria; 16, *leptothrix buccalis*; 17, *spirochaete denticola*; 18, superficial, 19, middle layer of bladder epithelium; 20, pus-corpuscles; 21, *schizomycetes*.  $\times 400$ .

**mucous catarrh** (*d, f, f<sub>1</sub>, g*). If a marked desquamation of the epithelium, with or without a mucoid change, occurs (Fig. 186, *a*), the condition is termed a **desquamative catarrh**; and such a process may occur not only on mucous membranes, but also in the respiratory parenchyma of the lungs, on serous surfaces (Fig. 180, *f, f<sub>1</sub>*), in the kidney-tubules, etc. If many pus-corpuscles are present in the exudate it may be spoken of as a **desquamative purulent** (Fig. 186, *a*), or finally as a pure **purulent catarrh**, in which condition the exudate becomes white or yellowish-white, milky or creamy.

The form and character of the cells of a catarrhal secretion vary with the location and the variety of catarrh (Fig. 187). Bacteria are often present in the cells of the exudate (Fig. 187, 4, 14, 15, 16, 17, 21).

If in a fluid exudate there occurs a deposition of fibrin or coagulation, there are formed **fibrinous** and **serofibrinous exudates**, which are often designated as **croupous**. These occur chiefly upon the surface of **serous and mucous membranes**, and in the lungs; but masses of fibrin

may be formed in tissues infiltrated with exudate, as well as in lymph-vessels.

On the mucous membranes the fibrinous exudates form whitish patches and coherent membranes, which sometimes lie upon them only loosely, but at other times are firmly attached to the underlying surface. In the serous cavities the fibrinous coagula float in the form of flakes in the fluid portion of the exudate, or form a firmly attached deposit upon the surface of the membranes. Such deposits consist at times only of thin, attached films or granules which give to the wiped-off surface a cloudy, lustreless, rough, or granular appearance; at other times of larger yellowish or yellowish-red, firm membranes, which often give to the surface a felted or villous appearance (*cor villosum*). In the lung, croupous inflammation leads to a filling of the alveoli with a coagulated mass, in consequence of which the lung acquires a firm consistency.

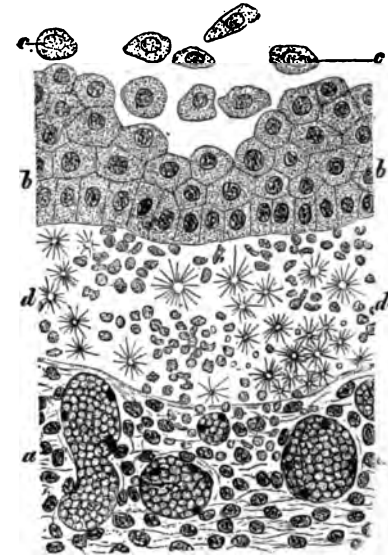


FIG. 188.—Acute hemorrhagic fibrinous inflammation of the trachea, caused by vapor of ammonia (Müller's fluid, hæmatoxylin, eosin). *a*, Superficial layer of the connective tissue of the mucosa, with greatly dilated blood-vessels and extravasated red blood-cells; *b*, deep layer of epithelium raised up *in toto*; *c*, desquamated epithelial cells; *d*, hemorrhagic fibrinous exudate with radiating, crystal-like masses of fibrin, in part proceeding from small, colorless spherules.  $\times 300$ .

in such a case, may follow gradually, or at other times more rapidly through the lifting up of whole layers of epithelium (Fig. 188, *b*), which are either well preserved or already degenerated or necrotic, and infiltrated with exudate (Fig. 190, *a*).

The exudation of fibrin may begin underneath the raised-up epithelium with the formation of fine needle-like forms resembling crystals (Fig. 188, *d*), which are arranged radially about a centre, in which at times there lies a small body, probably a product of the disintegration of a red corpuscle, or a blood-plate. Very soon there form thicker or thinner threads (Figs.

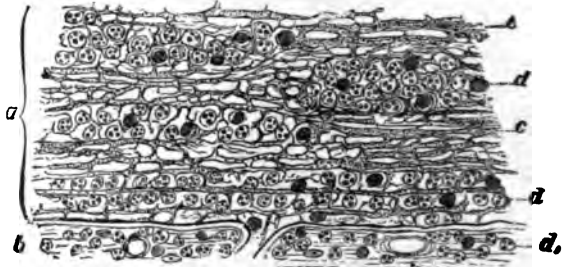


FIG. 189.—Croupous membrane from the trachea. *a*, Section through membrane; *b*, uppermost layer of the mucosa infiltrated with pus-corpuscles (*d*); *c*, fibrin threads and granules; *d*, pus-corpuscles.  $\times 250$ .



189, *c*; 190, *b*, *c*) which enclose a larger or smaller number of leucocytes and red blood-cells. The arrangement of the threads is usually reticular, but the thickness of the network and the size of the meshes vary greatly. When there is unequal development of the fibrin threads and strands, the principal strands sometimes lie parallel with the surface of the mucous membrane (Fig. 189, *a*), sometimes perpendicular to it



FIG. 190.—Section from an inflamed uvula covered with a stratified fibrinous membrane, from a case of diphtheritic croup of the pharyngeal organs (Müller's fluid, hæmatoxylin, eosin). *a*, Surface layer of coagulum, consisting of epithelial plates and fibrin and containing numerous colonies of cocci; *b*, second layer of coagulum, consisting of fine-meshed fibrin network enclosing leucocytes; *c*, third layer of coagulum, lying upon the connective tissue, and consisting of a wide-meshed reticulum of fibrin enclosing leucocytes; *d*, connective tissue infiltrated with cells; *e*, infiltrated boundary layer of the connective tissue of the mucous membrane; *f*, heaps of red blood-cells; *g*, widely dilated blood-vessels; *h*, dilated lymph-vessels filled with fluid, fibrin, and leucocytes; *i*, duct of a mucous gland distended with secretion; *k*, transverse section of a gland; *l*, fibrin reticulum in the superficial layer of connective tissue.  $\times 45$ .

(Fig. 190, *c*). Thick fibrinous membranes frequently show a distinct stratification (Fig. 190, *a*, *b*, *c*), indicating that their formation has occurred in successive batches pushed up from below.

When a mucous membrane becomes the seat of a deposition of fibrin, the underlying connective tissue is always more or less hyperæmic (Fig. 190, *g*), œdematous and swollen, infiltrated with leucocytes (Figs. 190, *d*, *e*; 191, *e*), and usually contains here and there also thready fibrin precipitates (Figs. 190, *l*; 191, *f*). Very often the tendency to the



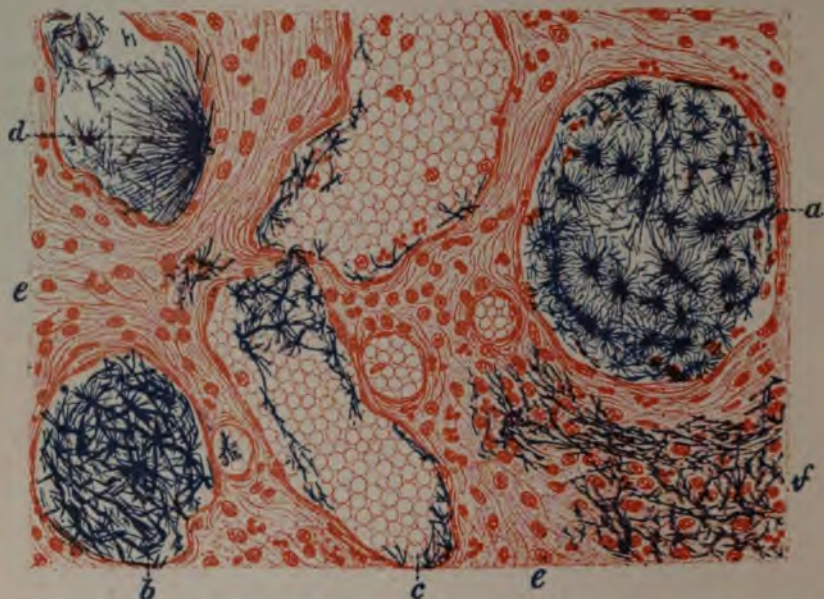


FIG. 191.—Croupous tracheitis. Section through the connective tissue of the mucosa (carmalum and fibrin-stain). *a, b, c, d*, Blood-vessels with fibrin precipitates; *e*, oedematously swollen connective tissue with leucocytes; *f*, connective tissue with fibrin-threads.  $\times 500$ .

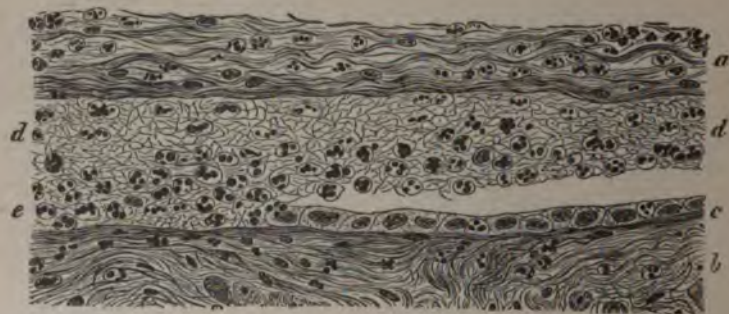


FIG. 192.—Traumatic fibrinopurulent peritonitis (alcohol, Van Gieson's). *a*, Peritoneum of the abdominal wall; *b*, serosa of a knuckle of intestine which had been sutured to the wall; *c*, epithelium remaining intact; *d*, *e*, fibrin-deposit.  $\times 200$ .



FIG. 193.—Fibrinous pleuritis (alcohol, Van Gieson's). *a*, Connective tissue; *b*, desquamated epithelium; *c*, thick, homogeneous, *d*, granular layer of fibrin with leucocytes.  $\times 100$ .

precipitation of fibrin is manifested also within the blood-vessels (Fig. 191), inasmuch as these contain at times tangled threads and rods of fibrin (Fig. 191, *b*), at other times fibrin-needles grouped in stellate forms or in clusters (*a, c, d*), which often proceed from degenerated endothelial cells or leucocytes, or from blood-plates, or radiate from portions of the vessel-wall where the endothelium is lost. Likewise, fibrin-threads may be also found in the dilated lymph-vessels, in association with fluid and cellular exudate (Fig. 190, *h*).

On the *serous membranes* the deposits of fibrin appear partly in granular (Fig. 193, *d*) and thready (Fig. 192, *d, e*), or in thick, homogeneous masses (Fig. 193, *c*), or even in the form of ribbon-like bands. Here also the epithelium is exfoliated at the point of deposition (Figs. 192, *d, e*; 193, *e*), but may be preserved in patches and covered over with fibrin (Fig. 192, *c*). The connective tissue of serous membranes in croupous inflammation is sometimes more, sometimes less infiltrated, and may contain leucocytes and fibrin, both in the congested vessels themselves (Fig. 191, *g*) and in the connective-tissue spaces (Figs. 191, *e, f*; 194, *c*). More marked exudations of fibrin upon the surface of serous membranes may produce thick, felted deposits, the formed elements of which consist of thready fibrin and pus corpuscles (Fig. 194, *d, e*), as well as micro-organisms (*b*). An abundance of pus-corpuscles gives to the exudate a *fibrinopurulent* character, the yellowish deposits becoming more whitish in color.

*Fibrinous exudates in the*



FIG. 194.—Fibrinopurulent diplococcus pleuritis in a three-year-old child (formalin, fibrin-stain). *a*, Inflamed pleura; *b*, diplococci; *c*, fibrin; *d*, *e*, fibrinopurulent exudate.  $\times 500$ .



*lungs* are characterized by the formation of a more or less close network of fibrin-threads (Fig. 195, *b*), in whose meshes and in the immediate neighborhood of which lie leucocytes and usually also red blood-cells (*c*), mingled with desquamated epithelium. In the first stages there are also found occasionally globular, wreath-shaped precipitates of fibrin joined together in rows. Fibrin-threads may develop also in and upon dead epithelium (Hauser).

In the *kidneys* deposits of fibrin may occur in the form of fine threads or hyaline masses in the urinary tubules and glomerular capsules. In the *lymph-glands* fibrin-threads are formed particularly in the lymph-channels.

**Hæmorrhagic exudate**—that is, an exudate containing large numbers of red cells—occurs especially in connection with the exudation of fibrin. The exudate of croupous pneumonia constantly contains a larger or smaller number of red blood-cells (Fig. 195, *c*), and likewise in fibrin-



FIG. 195.—Croupous pneumonia. Red hepatization of the lung (alcohol, carmine, fibrin-stain). *a*, Infiltrated alveolar septa; *b*, fibrinous exudate; *c*, red blood-cells.  $\times 200$ .

ous pericarditis and pleuritis great numbers of red blood-cells not infrequently escape from the vessels. Hæmorrhagic inflammations occur not infrequently in the central nervous system, in lymph-glands, in the skin and kidneys. In the last case the blood escapes from the glomerular vessels.

The serous, fibrinous, and serofibrinous inflammations are caused by thermal and chemical influences, as well as by bacteria; but are most frequently the result of infection, particularly of infection with the *Diplococcus pneumoniae* (Fig. 194, *b*) and the *Bacillus diphtheriae*. The former causes particularly croupous inflammations of the lungs and pleura, the latter gives rise to fibrinous inflammations of the throat, palate, and respiratory passages.

*Neumann* holds the opinion that in recent fibrinous inflammations of the serous membranes the hyaline bands and lumps on the surface of the membrane are not exudative fibrin, but represent layers of connective tissue that have undergone a fibrinoid degeneration. I cannot subscribe to this view, but agree rather with the majority of

writers who have expressed opinions upon this subject that the deposits are exudative fibrin. The illustrations which *Neumann* has presented in his work are in no manner confirmatory of his view, but enable us rather to affirm that *Neumann* had before him in his preparations exudative fibrin. In very severe inflammations fibrin may indeed be precipitated in the connective tissue of the serous membranes; and, when treated with stains, may occasion a peculiar staining of the tissue, but in such a case we have to deal with a deposit of exudative fibrin, and not with a fibrinoid degeneration of connective-tissue fibres.

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 See also §§ 90 and 98.



§ 93. When the inflammatory exudate is made up chiefly of leucocytes, there is produced within the tissue a **small-celled infiltration**

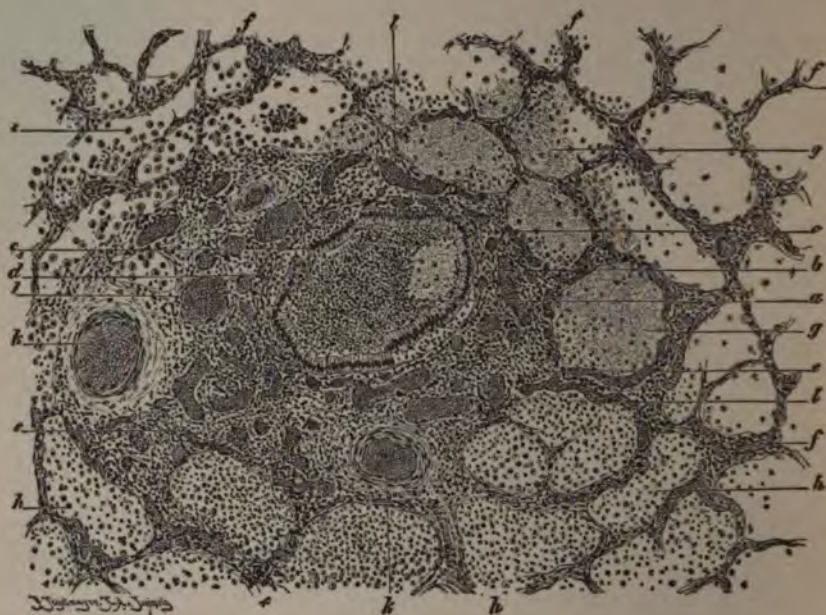


FIG. 196.—Purulent bronchitis, peribronchitis, and peribronchial bronchopneumonia in a child one year and three months old (Müller's fluid, hematoxylin, eosin). *a*, Purulent; *b*, mucoid bronchial contents; *c*, *c*<sub>1</sub>, bronchial epithelium infiltrated with round cells and partly desquamated; *d*, infiltrated bronchial wall with greatly dilated blood-vessels; *e*, infiltrated peribronchial and periarterial connective tissue; *f*, alveolar septa, in part infiltrated with cells; *g*, fibrinous exudate in the alveoli; *h*, alveoli filled with exudate rich in cells; *i*, alveoli filled with exudate containing few cells; *h*, cross-section of a pulmonary artery; *l*, bronchial, peribronchial, and interacinous vessels showing marked congestion.  $\times 43$ .

(Figs. 182, *b*; 196, *d*, *e*, *f*) which under certain conditions may be so marked that the structure of the tissue is more or less obscured. If leucocytes are present in large numbers in the fluid exudate on the surface

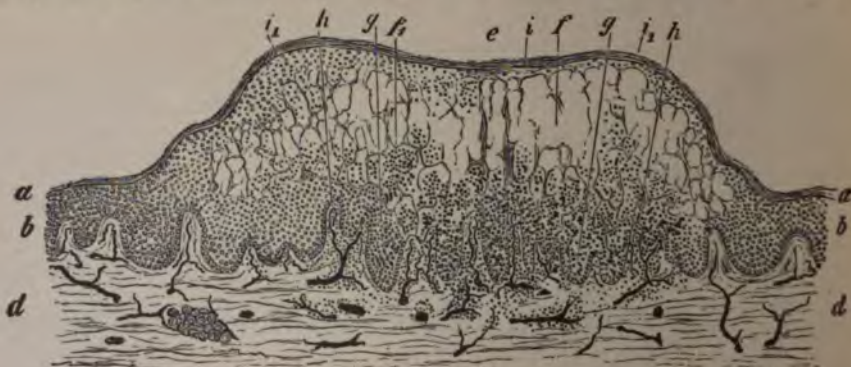


FIG. 197.—Section of a smallpox pustule (injected haematoxylin preparation). *a*, Horny layer; *b*, stratum mucosum of the epidermis; *d*, cutis; *e*, smallpox pustule; *f*, cavity of the pock, containing at *f*<sub>1</sub> pus-corpuscles; *g*, interpapillary remains of epithelium infiltrated with pus-corpuscles; *h*, umbilication with thin pock cover; *i*, edge of the pock, the roof at this point consisting of the horny and transitional layers.  $\times 25$ .

of a mucous membrane or external wound, there appears on the affected part a white fluid, which is called **pus**, and has given occasion for the designation of such an inflammation as a **purulent catarrh** (Fig. 196, *a*). A persistent marked secretion is termed a *blennorrhœa*. Collections of pus in the body cavities—for example, the pericardial, pleural, or joint-cavities—give rise to *purulent effusions* or **empyemata**. If within a blister arising through the liquefaction of the epithelial layers beneath the horny layer of the epidermis there takes place a marked collection of leucocytes, the fluid becomes more and more turbid, white, purulent, and the vesicle becomes changed into a **pustule** (Fig. 197, *f*).

The emigrating cells, particularly those in purulent inflammations, which are consequently known as **pus-corpuses**, are *polynuclear leu-*

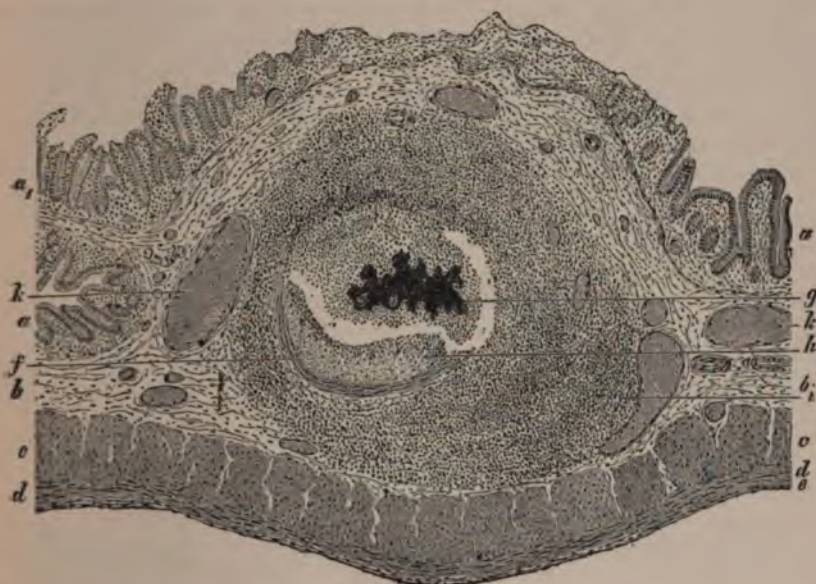


FIG. 198.—Embolic abscess of the intestinal wall with embolic purulent arteritis, and embolic aneurism in cross-section (alcohol, fuchsin). *a, b, c, d, e*, Layers of intestinal wall; *f*, remains of arterial wall, cross-section; *g*, embolus, surrounded by pus-corpuses lying within the dilated and partly suppurating artery; *h*, parietal thrombus; *i*, periarterial purulent infiltration of the submucosa; *k*, vein showing marked congestion.  $\times 28$ .

*cocytes*. They may reach the surface of a mucous membrane both after the desquamation of the epithelium and while it is still intact, in that they are able to pass between the epithelial cells (Fig. 196, *c, c*), and in the same manner the epithelium of the external skin may be penetrated by them (Fig. 197, *g*).

When leucocytes collect in such large numbers within a tissue as to give it a white, gray-white, or yellowish-white color the process assumes the character of a **purulent infiltration**. Should this be followed by liquefaction and dissolution of the tissue the process results finally in **tissue-suppuration** and **abscess-formation** (Fig. 198, *i*)—that is, in the formation of a cavity filled with pus.

When purulent infiltration and tissue-suppuration occur on the surface of an organ—for example, on a mucous membrane (Fig. 199, *d, f*,



g)—the process leads to a superficial loss of substance—an **ulcer**. The formation, through suppuration, of duct-like cavities gives rise to **fistulous tracts**.

The dissolution of the tissues, which is designated as suppuration, is possible only under the condition that they die. This tissue-necrosis is usually present before the occurrence of suppuration, and is caused by the specific action of the agent exciting the inflammation. The tissue may, however, die only during the course of inflammatory infiltration and then liquefy.

If an accumulation of pus-corpuscles is associated with an abundant collection of fluid, the **exudate** is spoken of as **seropurulent**; and such an exudate, when infiltrating the tissues, is often designated **purulent oedema**. The rapid spread of a purulent or seropurulent inflammation over wide areas—for example, through extensive areas of subcutaneous or submucosal tissues—is known as **phlegmon** (Fig. 200, c, d). This leads very often to the formation of extensive pus-cavities, in which there lie shreds of disintegrating tissue infiltrated with pus.

The association of serous exudation and fibrin precipitation with suppuration leads to the formation of **fibrinopurulent exudates** (Fig. 194, d, e); and effusions into the body-cavities, and meningeal exudates, as well as croupous exudates on mucous surfaces and in the lungs, and also phlegmons may bear this character. It is to be noted, however, that with the increase of suppuration the formation of fibrin becomes decreased, and the masses of coagula already present dissolve. The fibrin-masses infiltrated with pus are white and easily torn.

Suppurations and the associated formation of abscesses and ulcers are in the majority of cases caused by **bacteria**, most frequently by the *Staphylococcus pyogenes aureus*, *Streptococcus pyogenes*, and the *Gonococcus*;

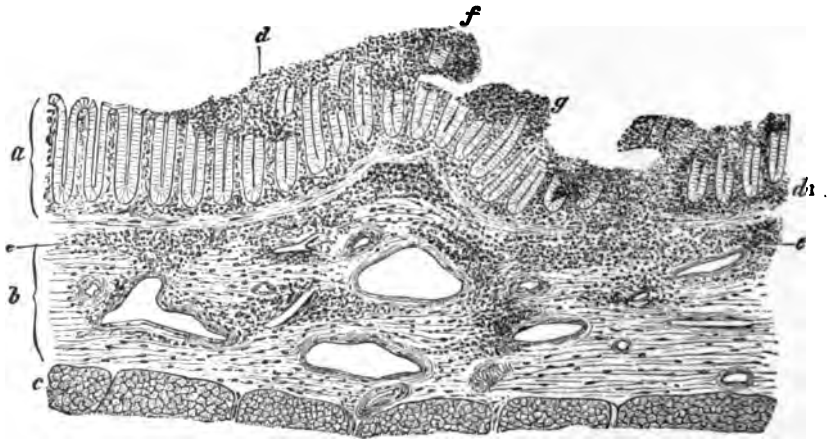


FIG. 199.—Suppuration and necrosis of the mucosa of the large intestine in dysentery (Müller's fluid, hæmatoxylin, eosin). Section through the mucosa (a) and submucosa (b) of the large intestine: c, muscularis; d, interglandular, d<sub>1</sub>, subglandular infiltration of the mucosa; e, focus of infiltration in the submucosa; f, infiltrated upper glandular layer undergoing desquamation; g, ulcer with infiltrated base. · 25.

but suppurations due to *Actinomyces*, *Bacillus typhi abdominalis*, *Diplococcus pneumoniae*, or the *Bacterium coli commune*, are not rare. The staphylococci generally produce localized inflammations; streptococci, on the other hand, phlegmonous. The presence of certain bacteria (*Bacillus*

*phlegmones emphysematosæ*, Fränkel; *Bacillus aerogenes capsulatus*, Welch) may cause the formation of **gas** (*gas phlegmon*). Suppuration is sometimes ectogenous, sometimes lymphogenous or hæmatogenous; and in the last case often bears the character of a metastatic process (Fig. 198).

Of the **chemical substances** which, when introduced into the tissues, can produce suppuration may be mentioned mercury, oil of turpentine, petroleum, five- to ten-per-cent. solutions of silver nitrate, creolin, digitoxin, dilute croton-oil, and sterilized cultures of various bacteria, in which the bacterial proteins are the active agents. The suppurations produced by chemical substances differ from those produced by infection, in that they heal more easily, do not spread in the tissues, and do not give rise to metastases, and through the fact that their products when inoculated possess no virulence.

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FIG. 200.—Phlegmon of the subcutaneous tissue with formation of a vesicle through oedema (Müller's fluid, hæmatoxylin, eosin). a, Corium; b, epidermis; c, infiltrated fat tissue; d, focus of pus; e, cellular foci in corium; f, subepithelial vesicle due to oedema.  $\times 30$ .

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See also §§ 90-92, Chapter X.

§ 94. As was explained in § 93, suppurative inflammation always leads to tissue-necrosis; but this necrosis is immediately lost sight of in the presence of the liquefaction and dissolution of the tissues which form the characteristic feature of suppuration. In other forms of action upon the tissues, there may occur a more extensive tissue-necrosis, recogniz-

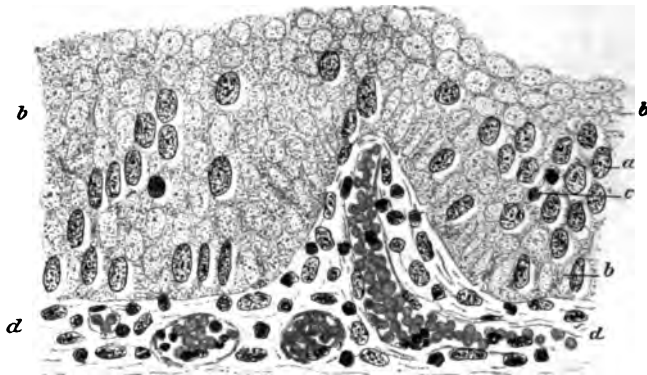


FIG. 201. Necrosis of the epithelium of the epiglottis (Müller's fluid, hæmatoxylin). *a*, Living epithelium with well-stained nuclei; *b*, necrotic epithelium with nuclei not staining; *c*, leucocytes lying in the epithelium; *d*, hyperemic, inflamed, and infiltrated connective tissue.  $\times 300$ .

able even to the unaided eye, which is not followed by suppuration, but on the other hand is characterized by the fact that the necrotic portions of the tissue remain unchanged for a long time, and only relatively late are removed through sequestration and sloughing or through absorption. Since the tissue-necrosis in such a case forms the chief feature, the condition may be appropriately designated a **necrotic inflammation**.

The tissue-necrosis associated with inflammation may be caused by caustic **chemicals**, **high** or **low temperatures**, and **ischæmia**, as well as by **infection** (typhoid fever, diphtheria, and dysentery).

Caustic chemicals cause tissue-necrosis in the first place in those tissues with which they first come into contact; but many substances (mercuric chloride, the salts of chromic acid, cantharidin) may cause necrosis only after their diffusion throughout the body in the blood and lymph. Such necrosis takes place particularly in the kidneys, the descending urinary passages, and in the intestines, where the substances causing the necrosis are excreted. Bacteria produce necrosis at the points where they multiply, and where the poisonous substances formed by them are collected in greater quantity.



The necrosis of the tissue may appear first of all as the immediate effect of the injurious action, the inflammatory exudation following later, and being confined to the region adjoining the necrosis; this is especially the case after the action of corrosive substances, and high temperature, and in ischaemia. In other cases, which belong chiefly to the infections, an inflammation is first established, the inflamed and infiltrated tissue later becoming necrosed. In tuberculous infections the necrosis occurs only after the tissue-proliferation has developed and has existed for some time.

Necrotic inflammations are most frequently seen on the mucous membranes, and are here usually called **diphtheritis**, particularly those which are caused by infection. The necrosis may at first affect the epithelium, which in consequence loses its nuclei (Fig. 201, *b*) and later acquires a lumpy appearance. If there are formed white, opaque patches upon the mucous membrane, as in the pharynx in diphtheria, the condition may be spoken of as *epithelial or superficial diphtheritis*. Usually, however, the designation *diphtheritis* is



FIG. 202.—Bacillary diphtheritis of the large intestine in dysentery (alcohol, gentian violet). *a*, Necrotic portion of the glandular layer of the mucosa, infiltrated with bacilli; *b*, intact inflamed mucosa; *c*, muscularis mucosae; *d*, submucosa; *e*, colonies of bacilli; *f*, glands with living epithelium; *g*, glands with necrotic epithelium and bacilli; *h*, connective tissue infiltrated with cells; *i*, blood-vessels.  $\times 80$ .



FIG. 203.—Section of the uvula in pharyngeal diphtheria with croupous deposits (alcohol, aniline brown). *a*, Normal epithelium; *b*, connective tissue of the mucous membrane; *c*, reticulated fibrin; *d*, connective tissue of mucosa infiltrated with coagulated fibrin and round cells, and partly necrotic; *e*, blood-vessels; *f*, haemorrhage; *g*, clumps of micrococci.  $\times 75$ .

applied only to tissue necroses in which the *inflamed and infiltrated connective tissue undergoes necrosis* (Fig. 202, *a*), and becomes converted into a lumpy or granular mass without nuclei, or into a more homogeneous mass containing fibrin, in which the structure of the tissue can no longer be recognized.

Diphtheritic sloughing of the tissues of a mucous membrane is ob-

served particularly often in the intestine (Fig. 202), but occurs also in other mucous membranes, as in those of the vagina, the descending urinary passages, and the region of the throat, where the tonsils are especially frequently affected, etc. The necrotic tissue forms white, or grayish-white, or, through the admixture of blood or bile or other impurities, dark green, yellow, brown, or otherwise colored sloughs, which are surrounded by reddened and inflamed tissue. If some time has already elapsed since its formation, and if a liquefaction of the tissue at the boundary between the living and dead tissues has occurred, with a separation of the latter, the necrosed parts form loosely attached or wholly free deposits lying on the surface of the membrane, these consisting at times only of small flakes, at other times of larger sloughs.

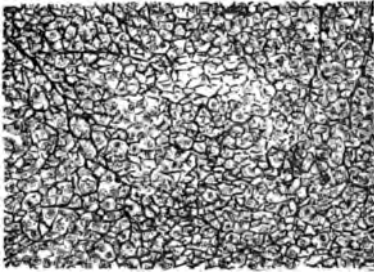


FIG. 204.—Diphtheritic necrosis within a swollen mesenteric lymph-gland, in typhoid fever (alcohol, fibrin-stain). Fibrin network between the necrotic cells.  $\times 300$ .

Diphtheritis of mucous membranes may be associated with croupous deposits (Fig. 203, *c*, *d*), so that the tissue-necrosis (*d*) may be covered over with fibrin (*c*).

Wound-granulations may also necrose in the same way as do inflamed mucous membranes; such a condition may therefore be called *wound-diphtheritis*.

Acute tissue-necroses caused by infection occur in the case of the internal organs, chiefly in the lymph-glands (Fig. 204), spleen and bone-marrow, and are characterized by the formation of opaque grayish-white, yellowish, or dirty-gray sloughs. Not infrequently fibrinous exudations are seen within the necrotic tissue (Figs. 203, *d*; 204).

In the necrosis caused by tuberculosis the destruction of the tissue occurs gradually, and bears the character of a **caseation**.

When an inflammatory focus contains bacteria which excite putrid decomposition of albuminoid bodies, the inflammation may take on the **character of a putrid gangrene**; and the tissue may disintegrate into a dirty gray or black, tinder-like mass which gradually dissolves and gives off an extremely disagreeable odor. Gas-bubbles are also sometimes developed in the focus.

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See also §§ 90-93.

## II. The Termination of Acute Inflammation in Healing.

§ 95. Should there occur in any tissue whatsoever an acute inflammation, sooner or later there always arise processes which have in aim the removal of the changes established and a restoration of the degenerated tissue, and which may therefore be regarded as **processes of repair**. If the cause which excited the inflammation is no longer present, these processes consist essentially in the *cessation of the pathological exudation* and its replacement by the *normal vascular secretion*, the *removal or absorption of the exudate present and of the necrotic tissue*, and the *restoration of the destroyed tissue*. If the *exciting cause of the inflammation* is still present in the tissue and active, it must be *removed or rendered inert*.

The **cessation of the alteration of the vessel-walls** is brought about through the restoration of the normal blood-supply to the damaged blood-vessels, so that the nutrition of the vessels again becomes normal. If the alteration was slight, and if the exciting cause of the inflammation had acted only for a short time—if it is the case, for example, only of the brief action of a trauma, or high temperature, or chemical substance, that was quickly removed—the restoration of the vessels may take place in a very short time, i.e., in a time that may be measured in minutes and hours.

When the exciting cause of the inflammation acts for some length of time—as, for example, in the case of bacteria which live and multiply in the tissues, or if changes are brought about through the inflammation itself, which act in such a manner as to alter the vessels—if there has been, for example, a tissue-necrosis—the vessels are subjected for some time to a continued harmful action, which hinders the complete restoration of their functions.

The **absorption of the exudate** occurs in many cases easily and quickly, in that it is taken up by the lymph-stream, eventually also by the blood. This takes place most quickly in the case of serous exudates, yet in many places fibrinous exudates may also be quite rapidly removed, but this occurs only when the coagula soon liquefy. Firmer fibrinous exudates, such as are formed especially upon the serous membranes, and also large collections of pus usually offer considerable resistance to absorption and are the cause of the prolonged course of the inflammation, although the character of this may become changed from what it was in the beginning. In very many cases absorption is accomplished by the simultaneous substitution, for the exudate, of embryonic tissue which later becomes changed into connective tissue.

The **sequestration and absorption of necrosed tissue**, with the exception of the casting-off of dead epithelium, which may be very quickly accomplished, always require a certain length of time, which varies according to the nature, situation, and extent of the necrosed tissue. In general, the inflammation persists as long as necrotic tissue is still present. *Superficial necrosed tissues may be cast off after sequestration*—that is, after the separation of the dead from the living tissues. In the case of deep-seated tissue-necroses in which the tissue does not soon undergo total liquefaction, *absorption* is usually slow, and is brought about through a gradual substitution of living tissue for the dead.

The **regeneration of the degenerated tissue** is dependent, for its occurrence, partly upon the degree and extent of the degeneration, partly upon the nature of the tissue, and partly upon the mode of action of the agent exciting the inflammation.

If the tissue-cells of the inflamed area are but slightly degenerated, they are quickly restored when the nutrition becomes normal. If single cells are lost but the organization of the whole is not disturbed, there can take place in most tissues a rapid renewal of cells through a regenerative growth of the remaining cells. This is true particularly of the different forms of connective tissue, the surface epithelium, liver- and kidney-cells, while ganglion-cells, bone-cells, cartilage-cells, and heart-muscle cells possess but little or no power of regeneration (see Chapter VI.). Extensive destruction of tissue with solutions of continuity, wounds, fractures, suppurations, necrotic inflammations, etc., lead to tissue-proliferations, which are indeed sufficient to close the defect, but for the greater part do not lead to a restoration of the normal tissue, but to the formation of a tissue of a lower grade, which in its earliest stages is known as **granulation tissue**, in its mature form as **cicatrical tissue**. Of the same character is also the tissue which in the course of time is substituted for exudates and tissue-necroses that are absorbed with difficulty.

With the entrance of regenerative proliferation and the formation of granulation tissue, there appears in the course of the inflammation a phenomenon which later gives to the inflammation an especial character, so that it may be designated a **proliferating inflammation**.

The **phenomena of proliferation** begin in inflamed tissues, at the earliest after eight hours, but are usually first clearly recognizable after from twenty-four to forty-eight hours.

In general, they appear the more rapidly the milder the inflammation and the more quickly the pathological exudation is overcome or diminished. Suppuration, necrosis, and gangrene of the tissues hinder proliferation and retard the beginning of repair, or at least confine the reparative processes to the neighboring tissues.

Every tissue capable of proliferation furnishes formative cells for tissue of its own kind or for one closely related to it. Pus-corpuscles are not formed by the tissue-cells; on the other hand, *cells newly developed from the tissue-cells by proliferation may become mixed with the exudate, degenerate in the same, and die.* Thus not all the cells newly developed through proliferation fulfil their function of producing new tissue.

The **removal of the exciting cause of inflammation** takes place very differently in different cases, and depends in the first place upon the nature of the cause. Many traumatisms and thermal influences act but for a short time, and have no further influence upon the course of the inflammation. Many substances acting chemically may be quickly taken up by the tissue-juices and made inert, or excreted, while others remain locally active for a longer time. Of the bacteria producing inflammation, many soon die, while others live and constantly produce new generations which in turn cause new inflammation, often in such a way that in the first diseased focus the inflammation may subside and healing take place, while in the neighborhood, or even in more distant regions, *metastatic inflammations* develop.

On account of the great differences which exist both in the nature and the behavior of the exciting cause of the inflammation, as well as in the course of the inflammatory tissue-degeneration and the exudation, and in the course of the healing processes, it is easy to understand that the whole

course of an inflammation, even to its termination in healing, may vary greatly in different cases, so that all the possibilities of its course can hardly be reviewed. At the same time it is not difficult to comprehend the decline of the different forms of inflammation, since ultimately the whole process is always made up of the same factors—that is, of tissue-degeneration, pathological exudation, and of proliferative processes, the last of which are calculated to remove the disturbances caused by the first two factors.

*Neumann* groups under the term inflammation all those phenomena which develop locally after a primary tissue-lesion, and are directed toward the healing of this lesion. According to this view, regeneration is, therefore, the most important part of the inflammatory process, in that it is especially adapted to restore the defect of tissue caused by the primary tissue-lesion, or, as *Neumann* puts it, to restore the uninterrupted continuity of the tissue. Such an identification of inflammation with regeneration I hold as inadmissible, in the first place because tissue-regenerations occur which clinically and anatomically in no way bear the character of an inflammatory process. Then also the inflammatory pathological exudations cannot be regarded as phenomena that can be compared with regeneration, and that like it, have for an end the healing of the primary tissue-lesion. Even if they act favorably in individual cases, this is not always true. Much more often do they cause serious damage which increases that established by the primary tissue-lesion, and often enough form a hindrance to the rapid entrance of the healing process.

In my opinion the tissue-proliferations do not form an essential part of inflammation; the inflammation already exists before they are established. Only in the late stages of inflammation do they form a part of the inflammatory process, and represent that part of the same which can bring about the healing. It is of no especial significance whether the processes of proliferation be regarded as a part of the later stages of inflammation or as a necessary sequela of the inflammatory tissue-degeneration, separated from the inflammation in a narrow sense, and considered under the point of view of tissue-repair.

### III. The Inflammatory New-formation of Tissue, Substitution of Exudates and Tissue-necroses by Connective Tissue.

§ 96. The **inflammatory proliferation of tissue** is essentially a regenerative process which has for its aim the compensation of the tissue-lesions produced by the causes of inflammation. Under especial conditions it leads not infrequently to a hyperplastic proliferation of connective tissue, frustrates its own aim, and causes new damage. This is particularly the case when, as the result of the persistence of the cause of the inflammation in the organism (chronic infection), or the persistence of the residue of the acute inflammation (exudate, abscess, tissue-necrosis), there is kept up a permanent condition of inflammation.

The inflammatory new-formations of tissue develop in essentially the same manner as the regenerative and hyperplastic tissue-proliferations described above (§§ 82–87). They are distinguished, however, from the simple regenerations by the fact that they are accompanied, at least during a part of their course, by disturbances of circulation and pathological exudations, and especially by an emigration of leucocytes, these factors exerting a modifying influence upon their course.

The **granulation tissue**, which forms in the course of an inflammation, is nothing more than an **embryonic tissue arising through cell-proliferation and infiltrated with leucocytes**. Primarily it consists of *cells* and *newly formed vessels* which at first depend for their support upon the ground-substance of the tissue from which they develop, but soon form for themselves a new ground-substance.

The **cells of the granulation tissue** are partly proliferated tissue-

cells (Fig. 205, *b*, *c*, *d*), and partly mono- and polynuclear leucocytes (*a*, *a*<sub>1</sub>). In the majority of cases the proliferated cells are connective-tissue cells, which later produce connective tissue (Fig. 205, *d*, *e*) and

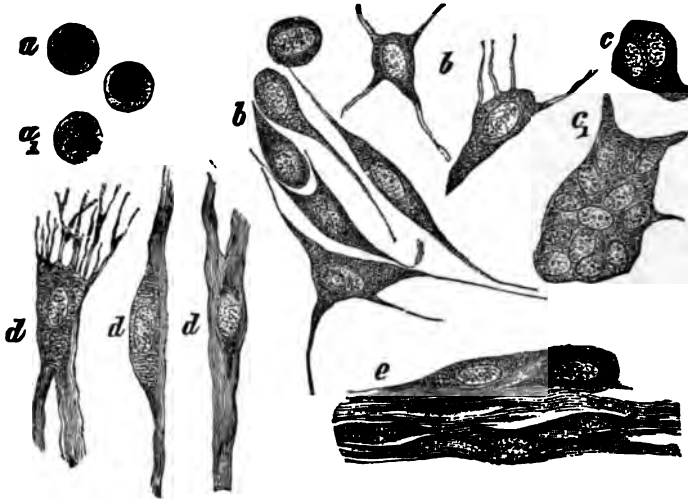


FIG. 205.—Isolated cells from a wound-granulation (Müller's fluid, picrocarmine). *a*, Mononuclear, *a*<sub>1</sub>, polynuclear leucocytes; *b*, different forms of mononuclear formative cells; *c*, formative cell with two nuclei; *c*<sub>1</sub>, multinuclear formative cell; *d*, formative cells in the stage of connective-tissue formation; *e*, fully developed connective tissue.  $\times 500$ .

are, therefore, known as **fibroblasts**. Granulation tissue may contain also the offspring of other tissue—for example, of periosteal tissue, marrow tissue, muscle tissue, or *osteoblasts*, *chondroblasts*, and *sarcoblasts*, which are able to form bone, cartilage, and muscle tissue. There may also be found in the granulation tissue developing within glands *newly formed glandular epithelium*, and in that developing in or upon mucous membranes or the integument, also newly formed *covering epithelium*; and these are able to produce *epithelial tissue-formations*. The *formative cells* of granulation tissue may move away from the place of their origin, and are thus in a certain sense *wandering cells*. In the formation of connective

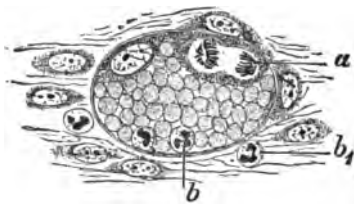


FIG. 206.—Cross-section of blood-vessel from the deep layers of the skin, forty hours after painting the skin of a rabbit with tincture of iodine (Flemming's solution, safranin). *a*, Endothelial cells with mitoses; *b*, *b*<sub>1</sub>, leucocytes.  $\times 350$ .

tissue they take on the most varied shapes (Fig. 205, *c*, *d*, *e*). At times they form also polynuclear cells (*c*<sub>1</sub>). They are characterized by large, bright, oval nuclei, which do not stain very deeply with nuclear stains, and are therefore distinguished from the nuclei of leucocytes which stain very intensely. The formative cells of the connective tissue are often termed *epithelioid cells* on account of their resemblance to epithelial cells.

The **leucocytes of granulation tissue** are cells which have wandered from the blood-vessels, and from their presence it may be concluded that the inflammatory exudation from the vessels still continues. Their number may in general be regarded as an index of the degree of the still existing inflammation complicating the recovery.

The **blood-vessels of granulation tissue** develop by offshoots from old vessels (see Fig. 160), which very soon, indeed at the time in which the emigration of leucocytes occurs (Fig. 206, *b, b*), give evidence of proliferative processes (*a*); and in the formation of granulation tissue they take on a very active growth. The young embryonic tissue is consequently very richly supplied with vessels, which give to it a red appearance. At the time of the transformation of granulation tissue into connective tissue or **scar tissue**, an *obliteration of the vessels* occurs, and the cicatrix consequently becomes pale.

If upon any part of the body-surface there occurs an **open wound**, which does not become infected with bacteria or seriously injured in any way, the edges and base of the wound after twenty-four hours become deep-red and somewhat swollen. The individual constituents of the tissue can still be clearly recognized, only the tissue appears somewhat swollen, and here and there small shreds of necrotic tissue may be seen. On the second day the gelatinous condition of the tissues is more apparent, the outlines of the individual tissue-elements are effaced, and the color becomes grayish-red. On the wound there lies a reddish-yellow fluid. From the second day on there appear over the whole wound small red papules, which rapidly increase in number and size, become confluent, and after two to three days form a granular red surface—a **granulation surface**. This is covered with a more or less abundant wound-secretion, which forms a gray, gelatinous layer, later becoming more yellow and creamy. This layer consists of a *coagulable exudate* rich in albumin and numerous round cells which usually possess lobulated or pigmented nuclei and are designated *pus-corpuscles*, and which, being incapable of further development, undergo disintegration.

The changes which the surface of the wound shows are in the first two days dependent upon the local hyperæmia and the infiltration of the tissue with cellular and fluid exudate, and upon the swelling and liquefaction of the tissue; after this time there is added thereto a tissue-proliferation with new-formation of vessels, leading to the development of **wound-granulations**. After a few days there will have developed in the wound a *granulation tissue* (Fig. 207, *a*) consisting of *fibroblasts and leucocytes*, and rich in *wide vessels* (*c*), and in which there very soon appears a *fibrillar ground-substance*. The leucocytes, which belong chiefly to the



FIG. 207.—Wound-granulations from an open wound with fibrinopurulent covering (Müller's fluid, hæmatoxylin). *a*, Granulation tissue; *b*, fibrinopurulent layer; *c*, blood-vessels.  $\times 135$ .



polynuclear form, are found in all the layers of the skin in fresh granulations, but heap themselves particularly in the superficial strata, and, *embedded in fibrin*, cover over the surface of the granulation tissue (*b*).

The freshly formed fibroblasts are round cells; later there develop cells partly club-shaped, partly spindle-shaped, partly with many branched processes (Fig. 205, *b, c, d*), which in various ways unite the cells. At the same time the number of the large formative cells increases, so that they finally surpass the small round cells in number, and in places come to lie closely together. When their number has reached a certain point, the development of connective tissue begins—i.e., the formation of the fibrillar intercellular substance (Figs. 205, *d, e*; 207, *a*)—which is completed in the manner described in § 84. When a certain degree of fibrillæ-formation has been reached the process comes to a standstill, the remains of the fibroblasts with their nuclei remain as fixed connective-tissue cells (Fig. 205, *e*), continue to live, and attach themselves to the surface of the bundles of fibrillæ. The process has then reached its termination—the *granulation tissue has become scar tissue*.

In open wounds of the skin, when infection does not disturb the course of healing, the formation of granulation tissue lasts until the wound is again covered with epithelium. The regeneration of the latter proceeds from the edges, the epithelium gradually pushing itself over the granulations. With the formation of connective tissue the reproductive processes essentially terminate, but transformation processes continue in the cicatricial tissue for some length of time. Shortly after its formation the cicatrix is rich in blood and appears red; later it loses a portion of its vessels through their obliteration, becomes pale, and contracts to a volume much less than the original. Large scars of the skin show permanently a smooth surface, since the papillary bodies are not again formed or only imperfectly (Fig. 209, *e*). The tissue of the scar remains for several months abnormally rich in cells, but in the course of time becomes poorer in cells and harder, and comes to contain elastic fibres.

When the healing of a wound occurs in such a manner that the tissue-defect is closed by the formation of a granulation tissue visible to the naked eye, the process is designated *repair by second intention* (*per secundam intentionem*).

The healing of incised wounds of the skin, whose edges, united by sutures, grow together by first intention, takes place in essentially the same manner as the healing of an open wound by second intention; but the processes of inflammation, proliferation, and new-formation of tissue are less prominent, partly because they take place below the skin, and partly because they are of much less extent and intensity.

The result of such a cut is always a more or less abundant exudation on the surfaces of the wound, forming a coagulated mass often containing blood (Fig. 208, *c*), which glues together the opposing wound-surfaces. Very soon there arises an inflammatory infiltration of the edges of the wound, which varies greatly in different cases, and when the course of repair is aseptic never reaches any significant degree (*g, h*), attaining its maximum in from two to four days, diminishing from the fifth to the seventh day, and completely disappearing at or soon after the end of the second week. The inflammatory infiltration is usually greater in the neighborhood of the wound-sutures than at the edges of the wound.

As early as the second day regenerative processes of proliferation begin in the connective tissue and in the vessels, and lead, in the course of several days, to the formation of an embryonic tissue, which lies partly

in the spaces of the connective tissue at the edges of the wound (Fig. 208, *f*), and partly extending into the open space of the wound itself (*i*); and here gradually grows into the coagulum which is present and replaces it. This tissue is usually present in varying quantity in different parts of the wound (Fig. 208), and may be entirely absent in places. After a certain number of days, the time varying according to the size of the

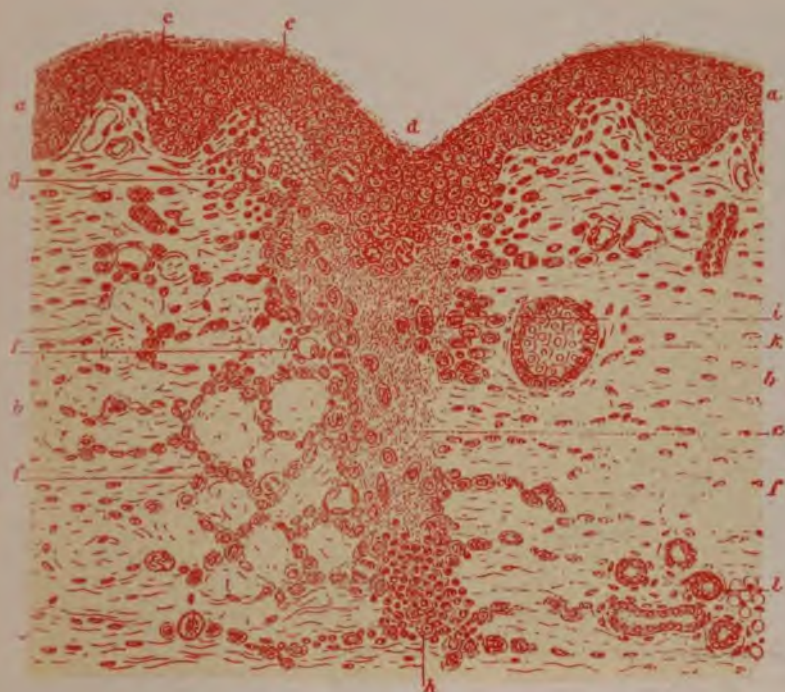


FIG. 208.—Healing of incised wound of skin united by suture (Flemming's solution, safranin). Preparation made on the sixth day. *a*, Epidermis; *b*, corium; *c*, fibrinous exudate, in part hæmorrhagic; *d*, newly formed epidermis, containing numerous division-figures, and with plugs of epithelium extending into the underlying exudate; *e*, division-figures in epithelium at a distance from the cut; *f*, proliferating embryonic tissue, developing from the connective-tissue spaces, and containing cells with nuclear division-figures, and in part also vessels with proliferating walls; *g*, proliferating embryonic tissue with leucocytes; *h*, focus of leucocytes in deepest angle of wound; *i*, fibroblasts lying within the exudate, one showing a nuclear division-figure; *k*, sebaceous-gland; *l*, sweat-gland.  $\times 70$ .

wound, the thickness of the exudate between the edges of the wound, and the intensity of the proliferation, the masses of embryonic tissue growing from the edges of the wound blend together, and there follows the formation of young connective tissue, which joins the edges of the wound together, and at the same time extends also into the old tissue, so that the boundary between the old and the new tissue becomes indistinct.

While connective tissue is being formed in the deeper parts of the wound, the epithelial covering on the surface is also being regenerated (Fig. 208), and indeed in this manner, that the epithelium pushes over the wound-surface, and through a continuous cell-division (*d*, *e*) forms an epithelial covering consisting of many layers. The epithelium may

push across the wound-surface even before a new-formation of cells has taken place.

The young connective tissue of the scar uniting the edges of the wound is distinguishable for a long time from the neighboring older tissue through its richness in cells (Fig. 209, *d, f*), as well as through the finer fibrillation of its ground-substance; and in large incised wounds of the skin there may be found in it, here and there, after the lapse of



FIG. 209.—Cutaneous portion of a laparotomy cicatrix, sixteen days after the operation (Müller's fluid, hematoxylin, Van Gieson's). *a*, Epithelium; *b*, corium; *c*, subcutaneous fat tissue; *d*, scar in corium; *e*, new epithelial covering; *f*, scar in fat tissue.  $\times 38$ .

weeks or even months, slight evidence of proliferation and inflammations. In general, however, transformation processes gradually occur in the blanching scar, so that its tissues come to approach more closely to the normal, and finally the place of the incision can no longer be easily recognized. If the wound heals by the interposition of abundant embryonic tissue, there may occur a defect of the papillary bodies (Fig. 209, *e*), so that the scar remains smooth.

§ 97. When there is found upon the surface of an **inflamed serous membrane** (Fig. 210, *a*) an **adherent layer of fibrin** (*b*), there usually develop quickly beneath it **granulation-formations**. The earliest beginnings of these can be seen as soon as the fourth day after the formation of the fibrinous deposit, and they consist at first of the appearance of *fibroblasts* (*f*) in the deepest layers of the fibrinous membrane. These arise through the proliferation of the connective-tissue cells of the affected serous membrane, and wander to the surface, and into the fibrin. In association with this phenomenon there follows very soon a new-forma-



tion of blood-vessels, and in the course of days or of weeks there is developed upon the surface a vascular embryonic tissue or granulation tissue, which, when the overlying fibrin layer is very compact, lifts this up *in toto* (Fig. 211, *b, c*); but, in the case of fibrin possessing a looser network, penetrates into the interstices of the fibrin-membrane (Figs. 210, *f*; 212, *b, d*), and in the course of time replaces the fibrin. Remains of the fibrin (Fig. 212, *c*) may, however, often persist for a long time, weeks or months, within the granulation tissue.

In the formation of the granulation tissue and the development of scar-tissue

the epithelium (endothelium) of the serous membranes takes no part, since it produces no fibroblasts. On the other hand, the products of the inflammatory proliferation become covered later with epithelium.

The final result of the process is the formation of **connective tissue**, which leads either to a *thickening* of the serosa which had been covered

with fibrin, or to an *adhesion* of the opposing surfaces of the serous membrane, so that the inflammation may be designated as *adhesive*. The result in individual cases depends partly upon the amount of the fibrin deposit and partly upon the situation of the affected organ, and its condition during the process of healing.

Small deposits of fibrin, limited to one surface of the serous membrane, lead only to thickenings of the serosa, which, becoming pale with the obliteration of the vessels, are represented finally by white thickenings frequently designated as **tendinous spots**. The



FIG. 210.—Fibrin deposit and beginning formation of granulation tissue in a fibrinous pericarditis five days old (Müller's fluid, hæmatoxylin). *a*, Epicardium; *b*, fibrin-membrane; *c*, dilated, congested vessels; *d*, round cells infiltrating the tissue; *e*, lymph-vessel filled with cells and clots; *f*, fibroblasts within the deposit.  $\times 150$ .



FIG. 211.—Development of granulation tissue in the pleura, in bronchopneumonia and pleuritis of fourteen days' duration (alcohol, Van Gieson). *a*, Hyperemic, infiltrated pleura; *b*, very vascular granulation tissue; *c*, fibrin; *d*, pus-corpuses, and granules of precipitated albumin.  $\times 100$ .

firm glueing together of two serous layers by an abundant deposit of fibrin leads also to a firm **adhesion** of the same through the abundant forma-





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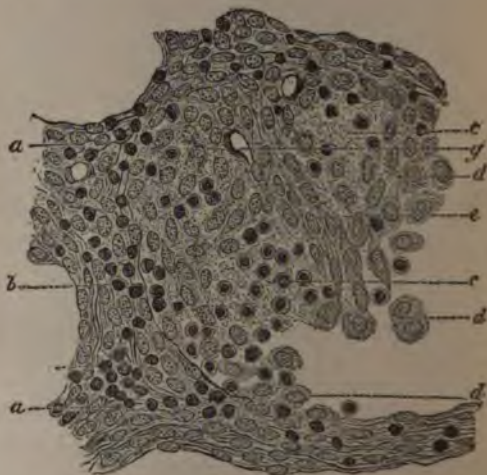


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FIG. 215—Border of a recent hæmorrhagic infarct of the lung (Müller's fluid, hæmatoxylin, eosin). *a*, Alveolar septa without nuclei, whose capillaries are filled with hyaline thrombi; *b*, septa, containing nuclei; *c*, vessels with red thrombi; *d*, *d*<sub>1</sub>, alveoli filled with coagulated blood; *e*, fibrinocellular exudate in the alveoli.  $\times 100$ .

imperfect substitution and liquefaction of the part not substituted, there arise strands and threads of connective tissue, which cross the lumen of the vessel. The calcification of portions of thrombi not substituted by

The **regeneration of the degenerated tissue** is dependent, for its occurrence, partly upon the degree and extent of the degeneration, partly upon the nature of the tissue, and partly upon the mode of action of the agent exciting the inflammation.

If the tissue-cells of the inflamed area are but slightly degenerated, they are quickly restored when the nutrition becomes normal. If single cells are lost but the organization of the whole is not disturbed, there can take place in most tissues a rapid renewal of cells through a regenerative growth of the remaining cells. This is true particularly of the different forms of connective tissue, the surface epithelium, liver- and kidney-cells, while ganglion-cells, bone-cells, cartilage-cells, and heart-muscle cells possess but little or no power of regeneration (see Chapter VI.). Extensive destruction of tissue with solutions of continuity, wounds, fractures, suppurations, necrotic inflammations, etc., lead to tissue-proliferations, which are indeed sufficient to close the defect, but for the greater part do not lead to a restoration of the normal tissue, but to the formation of a tissue of a lower grade, which in its earliest stages is known as **granulation tissue**, in its mature form as **cicatricial tissue**. Of the same character is also the tissue which in the course of time is substituted for exudates and tissue-necroses that are absorbed with difficulty.

With the entrance of regenerative proliferation and the formation of granulation tissue, there appears in the course of the inflammation a phenomenon which later gives to the inflammation an especial character, so that it may be designated a **proliferating inflammation**.

The **phenomena of proliferation** begin in inflamed tissues, at the earliest after eight hours, but are usually first clearly recognizable after from twenty-four to forty-eight hours.

In general, they appear the more rapidly the milder the inflammation and the more quickly the pathological exudation is overcome or diminished. Suppuration, necrosis, and gangrene of the tissues hinder proliferation and retard the beginning of repair, or at least confine the reparative processes to the neighboring tissues.

Every tissue capable of proliferation furnishes formative cells for tissue of its own kind or for one closely related to it. Pus-corpuscles are not formed by the tissue-cells; on the other hand, *cells newly developed from the tissue-cells by proliferation may become mixed with the exudate, degenerate in the same, and die*. Thus not all the cells newly developed through proliferation fulfil their function of producing new tissue.

The **removal of the exciting cause of inflammation** takes place very differently in different cases, and depends in the first place upon the nature of the cause. Many traumatisms and thermal influences act but for a short time, and have no further influence upon the course of the inflammation. Many substances acting chemically may be quickly taken up by the tissue-juices and made inert, or excreted, while others remain locally active for a longer time. Of the bacteria producing inflammation, many soon die, while others live and constantly produce new generations which in turn cause new inflammation, often in such a way that in the first diseased focus the inflammation may subside and healing take place, while in the neighborhood, or even in more distant regions, *metastatic inflammations* develop.

On account of the great differences which exist both in the nature and the behavior of the exciting cause of the inflammation, as well as in the course of the inflammatory tissue-degeneration and the exudation, and in the course of the healing processes, it is easy to understand that the whole

course of an inflammation, even to its termination in healing, may vary greatly in different cases, so that all the possibilities of its course can hardly be reviewed. At the same time it is not difficult to comprehend the decline of the different forms of inflammation, since ultimately the whole process is always made up of the same factors—that is, of tissue-degeneration, pathological exudation, and of proliferative processes, the last of which are calculated to remove the disturbances caused by the first two factors.

*Neumann* groups under the term inflammation all those phenomena which develop locally after a primary tissue-lesion, and are directed toward the healing of this lesion. According to this view, regeneration is, therefore, the most important part of the inflammatory process, in that it is especially adapted to restore the defect of tissue caused by the primary tissue-lesion, or, as *Neumann* puts it, to restore the uninterrupted continuity of the tissue. Such an identification of inflammation with regeneration I hold as inadmissible, in the first place because tissue-regenerations occur which clinically and anatomically in no way bear the character of an inflammatory process. Then also the inflammatory pathological exudations cannot be regarded as phenomena that can be compared with regeneration, and that like it, have for an end the healing of the primary tissue-lesion. Even if they act favorably in individual cases, this is not always true. Much more often do they cause serious damage which increases that established by the primary tissue-lesion, and often enough form a hindrance to the rapid entrance of the healing process.

In my opinion the tissue-proliferations do not form an essential part of inflammation; the inflammation already exists before they are established. Only in the late stages of inflammation do they form a part of the inflammatory process, and represent that part of the same which can bring about the healing. It is of no especial significance whether the processes of proliferation be regarded as a part of the later stages of inflammation or as a necessary sequela of the inflammatory tissue-degeneration, separated from the inflammation in a narrow sense, and considered under the point of view of tissue-repair.

### III. The Inflammatory New-formation of Tissue, Substitution of Exudates and Tissue-necroses by Connective Tissue.

§ 96. The inflammatory proliferation of tissue is essentially a regenerative process which has for its aim the compensation of the tissue-lesions produced by the causes of inflammation. Under especial conditions it leads not infrequently to a hyperplastic proliferation of connective tissue, frustrates its own aim, and causes new damage. This is particularly the case when, as the result of the persistence of the cause of the inflammation in the organism (chronic infection), or the persistence of the residue of the acute inflammation (exudate, abscess, tissue-necrosis), there is kept up a permanent condition of inflammation.

The inflammatory new-formations of tissue develop in essentially the same manner as the regenerative and hyperplastic tissue-proliferations described above (§§ 82–87). They are distinguished, however, from the simple regenerations by the fact that they are accompanied, at least during a part of their course, by disturbances of circulation and pathological exudations, and especially by an emigration of leucocytes, these factors exerting a modifying influence upon their course.

The **granulation tissue**, which forms in the course of an inflammation, is nothing more than an **embryonic tissue arising through cell-proliferation and infiltrated with leucocytes**. Primarily it consists of *cells* and *newly formed vessels* which at first depend for their support upon the ground-substance of the tissue from which they develop, but soon form for themselves a new ground-substance.

The **cells of the granulation tissue** are partly **proliferated tissue-**

cells (Fig. 205, *b*, *c*, *d*), and partly **mono- and polynuclear leucocytes** (*a* *a*<sub>1</sub>). In the majority of cases the proliferated cells are connective-tissue cells, which later produce connective tissue (Fig. 205, *d*, *e*) and

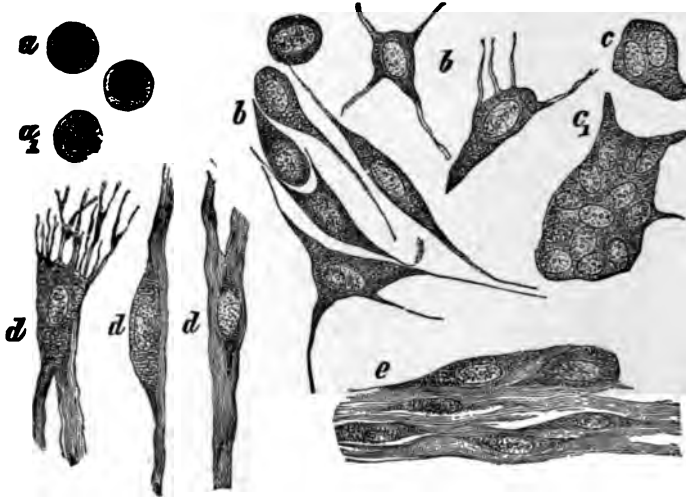


FIG. 205.—Isolated cells from a wound-granulation (Müller's fluid, picrocarmine). *a*, Mononuclear, *a*<sub>1</sub>, polynuclear leucocytes; *b*, different forms of mononuclear formative cells; *c*, formative cell with two nuclei; *c*<sub>1</sub>, multinuclear formative cell; *d*, formative cells in the stage of connective-tissue formation; *e*, fully developed connective tissue.  $\times 500$ .

are, therefore, known as **fibroblasts**. Granulation tissue may contain also the offspring of other tissue—for example, of periosteal tissue, marrow tissue, muscle tissue, or *osteoblasts*, *chondroblasts*, and *sarcoblasts*, which are able to form bone, cartilage, and muscle tissue. There may also be found in the granulation tissue developing within glands *newly formed glandular epithelium*, and in that developing in or upon mucous membranes or the integument, also newly formed *covering epithelium*; and these are able to produce *epithelial tissue-formations*. The *formative cells* of granulation tissue may move away from the place of their origin, and are thus in a certain sense *wandering cells*. In the formation of connective

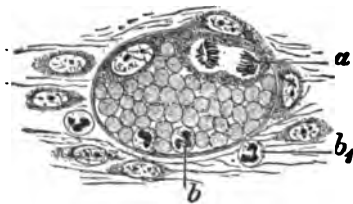


FIG. 206. Cross-section of blood-vessel from the deep layers of the skin, forty hours after painting the skin of a rabbit with tincture of iodine (Flemming's solution, safranin). *a*, Endothelial cells with mitoses; *b*, *b*<sub>1</sub>, leucocytes.  $\times 350$ .

tissue they take on the most varied shapes (Fig. 205, *c*, *d*, *e*). At times they form also polynuclear cells (*c*<sub>1</sub>). They are characterized by large, bright, oval nuclei, which do not stain very deeply with nuclear stains, and are therefore distinguished from the nuclei of leucocytes which stain very intensely. The formative cells of the connective tissue are often termed *epithelioid cells* on account of their resemblance to epithelial cells.

The **leucocytes of granulation tissue** are cells which have wandered from the blood-vessels, and from their presence it may be concluded that the inflammatory exudation from the vessels still continues. Their number may in general be regarded as an index of the degree of the still existing inflammation complicating the recovery.



The **blood-vessels of granulation tissue** develop by offshoots from old vessels (see Fig. 160), which very soon, indeed at the time in which the emigration of leucocytes occurs (Fig. 206, *b*, *b*<sub>1</sub>) give evidence of proliferative processes (*a*); and in the formation of granulation tissue they take on a very active growth. The young embryonic tissue is consequently very richly supplied with vessels, which give to it a red appearance. At the time of the transformation of granulation tissue into connective tissue or **scar tissue**, an *obliteration of the vessels* occurs, and the cicatrix consequently becomes pale.

If upon any part of the body-surface there occurs an **open wound**, which does not become infected with bacteria or seriously injured in any way, the edges and base of the wound after twenty-four hours become deep-red and somewhat swollen. The individual constituents of the tissue can still be clearly recognized, only the tissue appears somewhat swollen, and here and there small shreds of necrotic tissue may be seen. On the second day the gelatinous condition of the tissues is more apparent, the outlines of the individual tissue-elements are effaced, and the color becomes grayish-red. On the wound there lies a reddish-yellow fluid. From the second day on there appear over the whole wound small red papules, which rapidly increase in number and size, become confluent, and after two to three days form a granular red surface—a **granulation surface**. This is covered with a more or less abundant wound-secretion, which forms a gray, gelatinous layer, later becoming more yellow and creamy. This layer consists of a *coagulable exudate* rich in albumin and numerous round cells which usually possess lobulated or pigmented nuclei and are designated *pus-corpuscles*, and which, being incapable of further development, undergo disintegration.

The changes which the surface of the wound shows are in the first two days dependent upon the local hyperæmia and the infiltration of the tissue with cellular and fluid exudate, and upon the swelling and liquefaction of the tissue; after this time there is added thereto a tissue-proliferation with new-formation of vessels, leading to the development of **wound-granulations**. After a few days there will have developed in the wound a *granulation tissue* (Fig. 207, *a*) consisting of *fibroblasts and leucocytes*, and rich in *wide vessels* (*c*), and in which there very soon appears a *fibrillar ground-substance*. The leucocytes, which belong chiefly to the



FIG. 207.—Wound-granulations from an open wound with fibrinopurulent covering (Müller's fluid, hæmatoxylin). *a*, Granulation tissue; *b*, fibrinopurulent layer; *c*, blood-vessels.  $\times 135$ .



polynuclear form, are found in all the layers of the skin in fresh granulations, but heap themselves particularly in the superficial strata, and, *embedded in fibrin*, cover over the surface of the granulation tissue (*b*).

The freshly formed fibroblasts are round cells; later there develop cells partly club-shaped, partly spindle-shaped, partly with many branched processes (Fig. 205, *b, c, d*), which in various ways unite the cells. At the same time the number of the large formative cells increases, so that they finally surpass the small round cells in number, and in places come to lie closely together. When their number has reached a certain point, the development of connective tissue begins—i.e., the formation of the fibrillar intercellular substance (Figs. 205, *d, e*; 207, *a*)—which is completed in the manner described in § 84. When a certain degree of fibrillæ-formation has been reached the process comes to a standstill, the remains of the fibroblasts with their nuclei remain as fixed connective-tissue cells (Fig. 205, *e*), continue to live, and attach themselves to the surface of the bundles of fibrillæ. The process has then reached its termination—the *granulation tissue has become scar tissue*.

In open wounds of the skin, when infection does not disturb the course of healing, the formation of granulation tissue lasts until the wound is again covered with epithelium. The regeneration of the latter proceeds from the edges, the epithelium gradually pushing itself over the granulations. With the formation of connective tissue the reproductive processes essentially terminate, but transformation processes continue in the cicatricial tissue for some length of time. Shortly after its formation the cicatrix is rich in blood and appears red; later it loses a portion of its vessels through their obliteration, becomes pale, and contracts to a volume much less than the original. Large scars of the skin show permanently a smooth surface, since the papillary bodies are not again formed or only imperfectly (Fig. 209, *e*). The tissue of the scar remains for several months abnormally rich in cells, but in the course of time becomes poorer in cells and harder, and comes to contain elastic fibres.

When the healing of a wound occurs in such a manner that the tissue-defect is closed by the formation of a granulation tissue visible to the naked eye, the process is designated *repair by second intention* (*per secundam intentionem*).

The healing of incised wounds of the skin, whose edges, united by sutures, grow together by first intention, takes place in essentially the same manner as the healing of an open wound by second intention; but the processes of inflammation, proliferation, and new-formation of tissue are less prominent, partly because they take place below the skin, and partly because they are of much less extent and intensity.

The result of such a cut is always a more or less abundant exudation on the surfaces of the wound, forming a coagulated mass often containing blood (Fig. 208, *c*), which glues together the opposing wound-surfaces. Very soon there arises an inflammatory infiltration of the edges of the wound, which varies greatly in different cases, and when the course of repair is aseptic never reaches any significant degree (*g, h*), attaining its maximum in from two to four days, diminishing from the fifth to the seventh day, and completely disappearing at or soon after the end of the second week. The inflammatory infiltration is usually greater in the neighborhood of the wound-sutures than at the edges of the wound.

As early as the second day regenerative processes of proliferation begin in the connective tissue and in the vessels, and lead, in the course of several days, to the formation of an embryonic tissue, which lies partly

in the spaces of the connective tissue at the edges of the wound (Fig. 208, *f*), and partly extending into the open space of the wound itself (*i*); and here gradually grows into the coagulum which is present and replaces it. This tissue is usually present in varying quantity in different parts of the wound (Fig. 208), and may be entirely absent in places. After a certain number of days, the time varying according to the size of the

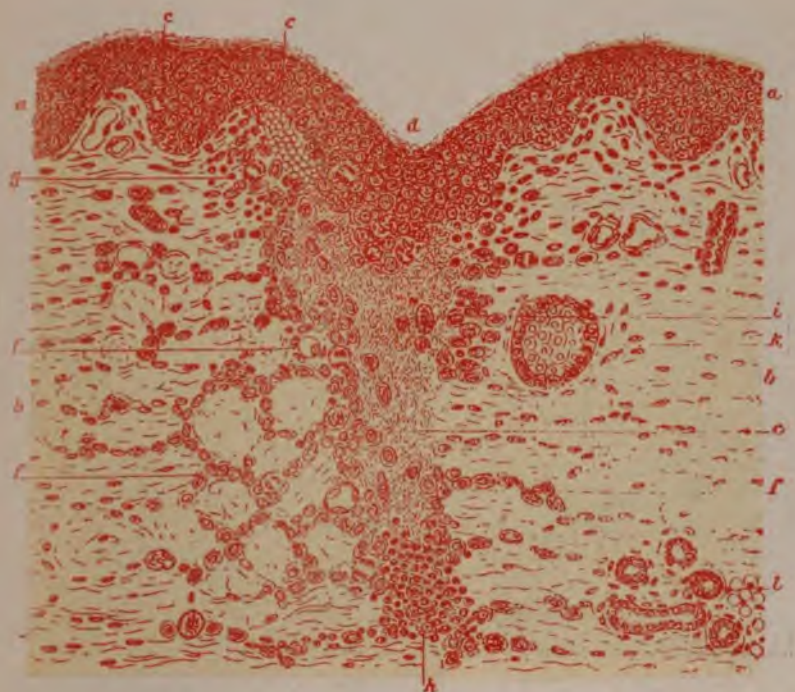


FIG. 208.—Healing of incised wound of skin united by suture (Flemming's solution, safranin). Preparation made on the sixth day. *a*, Epidermis; *b*, corium; *c*, fibrinous exudate, in part hemorrhagic; *d*, newly formed epidermis, containing numerous division-figures, and with plugs of epithelium extending into the underlying exudate; *e*, division-figures in epithelium at a distance from the cut; *f*, proliferating embryonic tissue, developing from the connective-tissue spaces, and containing cells with nuclear division-figures, and in part also vessels with proliferating walls; *g*, proliferating embryonic tissue with leucocytes; *h*, focus of leucocytes in deepest angle of wound; *i*, fibroblasts lying within the exudate, one showing a nuclear division-figure; *k*, sebaceous-gland; *l*, sweat-gland.  $\times 70$ .

wound, the thickness of the exudate between the edges of the wound, and the intensity of the proliferation, the masses of embryonic tissue growing from the edges of the wound blend together, and there follows the formation of young connective tissue, which joins the edges of the wound together, and at the same time extends also into the old tissue, so that the boundary between the old and the new tissue becomes indistinct.

While connective tissue is being formed in the deeper parts of the wound, the epithelial covering on the surface is also being regenerated (Fig. 208), and indeed in this manner, that the epithelium pushes over the wound-surface, and through a continuous cell-division (*d*, *e*) forms an epithelial covering consisting of many layers. The epithelium may

push across the wound-surface even before a new-formation of cells has taken place.

The young connective tissue of the scar uniting the edges of the wound is distinguishable for a long time from the neighboring older tissue through its richness in cells (Fig. 209, *d, f*), as well as through the finer fibrillation of its ground-substance; and in large incised wounds of the skin there may be found in it, here and there, after the lapse of



FIG. 209.—Cutaneous portion of a laparotomy cicatrix, sixteen days after the operation (Müller's fluid, hæmatoxylin, Van Gieson's). *a*, Epithelium; *b*, corium; *c*, subcutaneous fat tissue; *d*, scar in corium; *e*, new epithelial covering; *f*, scar in fat tissue.  $\times 38$ .

weeks or even months, slight evidence of proliferation and inflammations. In general, however, transformation processes gradually occur in the blanching scar, so that its tissues come to approach more closely to the normal, and finally the place of the incision can no longer be easily recognized. If the wound heals by the interposition of abundant embryonic tissue, there may occur a defect of the papillary bodies (Fig. 209, *e*), so that the scar remains smooth.

§ 97. When there is found upon the surface of an **inflamed serous membrane** (Fig. 210, *a*) an **adherent layer of fibrin** (*b*), there usually develop quickly beneath it **granulation-formations**. The earliest beginnings of these can be seen as soon as the fourth day after the formation of the fibrinous deposit, and they consist at first of the appearance of *fibroblasts* (*f*) in the deepest layers of the fibrinous membrane. These arise through the proliferation of the connective-tissue cells of the affected serous membrane, and wander to the surface, and into the fibrin. In association with this phenomenon there follows very soon a new-forma-



tion of blood-vessels, and in the course of days or of weeks there is developed upon the surface a vascular embryonic tissue or granulation tissue, which, when the overlying fibrin layer is very compact, lifts this up *in toto* (Fig. 211, *b, c*); but, in the case of fibrin possessing a looser network, penetrates into the interstices of the fibrin-membrane (Figs. 210, *f*; 212, *b, d*), and in the course of time replaces the fibrin. Remains of the fibrin (Fig. 212, *c*) may, however, often persist for a long time, weeks or months, within the granulation tissue.

In the formation of the granulation tissue and the development of scar-tissue

the epithelium (endothelium) of the serous membranes takes no part, since it produces no fibroblasts. On the other hand, the products of the inflammatory proliferation become covered later with epithelium.

The final result of the process is the formation of **connective tissue**, which leads either to a *thickening* of the serosa which had been covered

with fibrin, or to an *adhesion* of the opposing surfaces of the serous membrane, so that the inflammation may be designated as *adhesive*. The result in individual cases depends partly upon the amount of the fibrin deposit and partly upon the situation of the affected organ, and its condition during the process of healing.

Small deposits of fibrin, limited to one surface of the serous membrane, lead only to thickenings of the serosa, which, becoming pale with the obliteration of the vessels, are represented finally by white thickenings frequently designated as **tendinous spots**. The



FIG. 210.—Fibrin deposit and beginning formation of granulation tissue in a fibrinous pericarditis five days old (Müller's fluid, hematoxylin). *a*, Epicardium; *b*, fibrin-membrane; *c*, dilated, congested vessels; *d*, round cells infiltrating the tissue; *e*, lymph-vessel filled with cells and clots; *f*, fibroblasts within the deposit.  $\times 150$ .



FIG. 211.—Development of granulation tissue in the pleura, in bronchopneumonia and pleuritis of fourteen days' duration (alcohol, Van Gieson). *a*, Hyperemic, infiltrated pleura; *b*, very vascular granulation tissue; *c*, fibrin; *d*, pus-corpuscles, and granules of precipitated albumin.  $\times 100$ .

firm glueing together of two serous layers by an abundant deposit of fibrin leads also to a firm **adhesion** of the same through the abundant forma-





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**Masses of coagula within blood-vessels**, which are called thrombi, give rise, in case no infection occurs, to an inflammatory—that is, associated with cell-emigration—proliferation of the vessel-wall, a *proliferating vasculitis*. This process corresponds exactly to the inflammatory proliferation of the serous membranes. It is entirely immaterial whether the thrombosis has been caused by a preceding inflammatory process or by any other conditions, inasmuch as the presence of the mass of coagulum is sufficient to cause inflammation and tissue-proliferation.

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tion of connective tissue. In the case of a smaller amount of fibrin, and repeated rubbing of the membranes upon each other, there develop only loose *membranous* or *stringy adhesions*, which still permit the serous surfaces to move upon one another. Very large amounts of *fibrin* may also, under certain conditions, in part permanently resist absorption, so that they remain lying within the newly formed connective tissue, and then usually become *calcified*.

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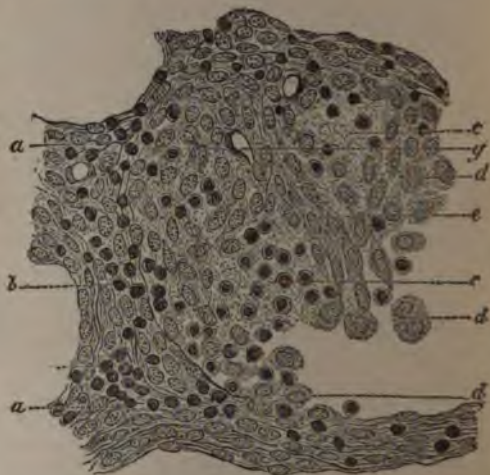


FIG. 213.—Intraseptal and intra-alveolar formation of connective tissue in the lung (alcohol, hæmatoxylin). *a*, Thickened fibrocellular alveolar septum, in part infiltrated with round cells (*b*); *c*, fibrinocellular exudate in the alveoli; *d*, intra-alveolar formative cells; *e*, strand of spindle-cell fibroblasts; *g*, intra-alveolar newly formed blood-vessel.  $\times 200$ .



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the substitution of a parietal thrombus, on the other hand, results in the formation of fibrous thickenings of the vessel-wall. As the result of an



FIG. 214—Development of embryonic tissue in a thrombosed femoral artery of an old man, three weeks after ligation (alcohol, hæmatoxylin). *a*, Media; *b*, elastic limiting membrane; *c*, intima, thickened through older inflammatory processes; *d*, coagulated blood; *e*, cellular infiltration of the media, *f*, of the intima; *g*, round cells, partly in the thrombus, partly between it and the intima; *h*, different forms of formative cells.  $\times 300$ .



FIG. 215—Border of a recent hæmorrhagic infarct of the lung (Müller's fluid, hæmatoxylin, eosin). *a*, Alveolar septa without nuclei, whose capillaries are filled with hyaline thrombi; *b*, septa, containing nuclei; *c*, vessels with red thrombi; *d*, *d*<sub>1</sub>, alveoli filled with coagulated blood; *e*, fibrinocellular exudate in the alveoli.  $\times 100$ .

imperfect substitution and liquefaction of the part not substituted, there arise strands and threads of connective tissue, which cross the lumen of the vessel. The calcification of portions of thrombi not substituted by

connective tissue leads to the formation of vessel-stones (arterio- or phleboliths).

**Necrotic tissue**, which cannot be sequestered and discharged externally, is also **replaced by a vascular connective tissue**, which becomes converted into **scar tissue**; and this substitution takes place in the same manner as in the case of fibrinous exudates and thrombi. The requisite condition for this substitution is that the necrotic tissue shall contain no substances (bacteria) which hinder tissue-proliferation or excite severe inflammation. In general it is immaterial how the necrosis has occurred, and whether the necrotic tissue is free from exudate or is infiltrated with exudate or blood (Fig. 215, *d*, *d*<sub>1</sub>). The first phenomenon leading to healing is the association with the inflammatory exudate (*e*), in the neighborhood of the necrosis, of a tissue-proliferation, which produces **granulation tissue**, which grows toward the necrotic tissue (Fig. 216, *d*, *e*), dissolves it, and finally replaces it. If this process is not disturbed by any influence whatever, even very large tissue-necroses may in the course of weeks and months be made to disappear and may be replaced by connective tissue. It may also happen, however, that certain tissues resist absorption, or that the development of granulation tissue stops so early that remains of the *necrosed tissues persist and later become calcified*.

When, as the result of an inflammation or ischæmia within an organ, only the more sensitive elements die—for example, epithelial or muscle cells—while the connective tissue remains intact, the absorption of the



FIG. 216.—Periphery of a healing pulmonary infarct (Möller's fluid, hæmatoxylin, eosin). *a*, Blood-extravasate changed into a yellowish granular mass; *b*, necrotic alveolar septa without nuclei; *c*, newly formed connective tissue; *d*, vascular granulation tissue within the alveoli; *e*, fibroblasts within alveoli containing the residue of the hemorrhage; *f*, artery; *g*, vascular connective tissue formed within the artery at the place of the embolus.  $\times 40$ .

necrotic portions takes place very quickly, and there is formed within a short time a *scar* or *callus of connective tissue* (Fig. 217, *e*), in which the specific tissue-elements are lacking.

**Pus** is quickly absorbed from small abscesses, and the defect closed by



*granulation and scar tissue.* Large amounts of pus may be absorbed from the body-cavities and from the lungs.

**Abscesses** cause in their neighborhood a **proliferation of granulation tissue** which leads to the formation of an **abscess-membrane**. The abscess-cavity may become obliterated through the absorption of the pus and the growing together of the granulation-membrane covering the walls of the cavity; the abscess finally heals and leaves a **scar**. Incomplete absorption may lead to thickening of the pus and later a **calcification of the residue**. If the pus does not become inspissated, the **abscess may persist** and in the course of time may be increased in size by secretion from its walls.

**Empyemata** may heal in a similar manner to abscesses through absorption of the pus. At the time of absorption the tissues enclosing the pus produce **granulation and scar tissue**, which may reach a considerable size when the process of absorption takes a long time (Fig. 223). When incompletely absorbed, *calcification of the thickened pus may occur*.

**Foreign bodies**, so far as they are absorbable and exert no specific influence upon their surroundings, are likewise dissolved, and replaced by connective tissue in the same way as are tissue-necroses or fibrin masses. If they possess accessible interstices, these may be penetrated by granulation tissue. If their mass cannot be absorbed, they become encapsulated (Fig. 217).

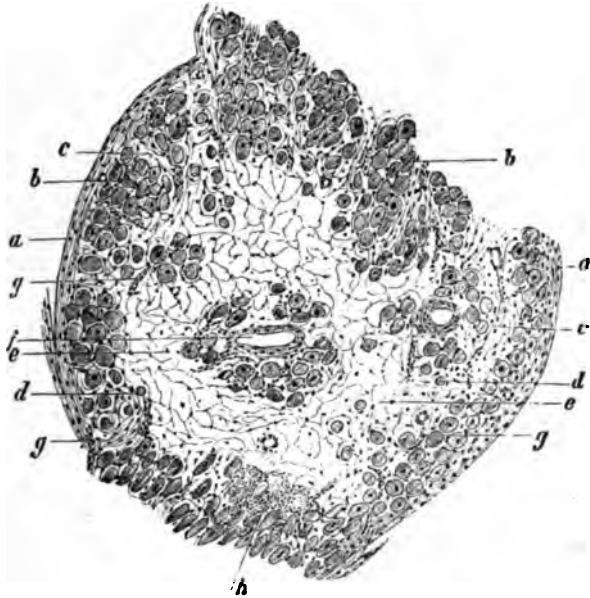


FIG. 217.—Fibroid area in heart-muscle. Section through a muscle-trabecula which has undergone fibroid change (Müller's fluid, hæmatoxylin). *a*, Endocardium; *b*, cross-section of normal muscle-cells; *c*, hyperplastic connective tissue rich in cells; *d*, atrophic muscle-cells in hyperplastic connective tissue; *e*, dense connective tissue, poor in nuclei and containing no muscle-cells; *f*, vein, in whose neighborhood muscle-cells are still preserved; *g*, small blood-vessels; *h*, small-celled infiltration.  $\times 40$ .

The rôle played in the course of inflammation by the **leucocytes which emigrate from the blood-vessels** has not yet been satisfactorily explained. It is certain that the polynuclear leucocytes undergo no progressive changes, but either wander farther or die, and in part are taken up and destroyed by the fibroblasts (see § 98). The fate of the mononuclear leucocytes, particularly of the larger forms, is not definitely known. By the majority of authors it is assumed that they also take no part in the development of connective tissue, and that there is no hæmatogenous formation of connective tissue. It is, however, to be noted that many authors (*Arnold, Metschnikoff, Schottländer, Krompecher*) hold that emigrated leucocytes may become transformed into fibroblasts. The basis of this difference of opinion rests upon the fact that the cells in question—round fibroblasts and mononuclear leucocytes—are very similar to each other, and forms often appear whose origin cannot be definitely determined. Therefore it cannot be said with

certainly whether the so-called **small-celled infiltration**—that is, the collection of mononuclear round cells in the tissue—which is so frequently seen in inflammation, is of hæmatogenous origin, or whether in part it is made up of proliferated tissue-cells. *Ribbert* believes that there is reason for regarding these collections of cells as lymph-nodes.

Recently there have been differentiated among the cells of the perivascular foci especial forms, as **plasma-cells** (*Unna*) or "*Krümelzellen*" (*von Marschalkó*). These are mononuclear, round or oval, occasionally also long cells (*von Marschalkó*, *Krompecher*) which stain deeply with methylene-blue, and, as a result of the close clumping of the protoplasm at the periphery of the cell, show a light area around the nucleus which is usually excentrically placed and is furnished with a chromatin-network and five to eight chromatin granules. *Unna*, who first described these cells, regarded them as offspring of the connective tissue which die. On the other hand, *von Marschalkó*, *Schottländer*, *Krompecher*, and *Justi* regard them as offspring of leucocytes, and it is probable that their view is the correct one. *Von Marschalkó* regards it as probable that they produce connective tissue; *Schottländer* and *Krompecher* are convinced that they become changed into fibroblasts and can form connective tissue. *Plasma-cells, therefore, represent transition stages between the hæmatogenous wandering-cells and connective-tissue cells.*

According to the investigations made up to the present time, it is not possible to make positive statements regarding the significance and fate of the emigrating hæmatogenous wandering-cells. The possibility that they are able to form connective-tissue cells is conceded, but is not a proved fact. It is also possible that among the emigrating leucocytes there are cells arising from proliferating endothelium of the blood-vessels, or that young motile connective-tissue cells wander into the vessels and then again pass out, and that the last two named are able to form connective tissue. For the solution of these problems we must look to new investigations.

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- See also §§ 90 and 98.



#### IV. Phagocytosis Occurring in the Course of Inflammations, and the Formation of Foreign-body Giant-cells.

§ 98. The presence in the tissues of the human body of **small foreign bodies** or of **dead tissue-elements** and **tissue-detritus** leads very often to a marked *collection of cells* about the embedded substance. At first these cells are *leucocytes* which have wandered out from the vessels, but later *proliferating tissue-cells which have become motile* wander into the neighborhood of the foreign body or dead tissue-remains.

According to investigations by Leber, Buchner, Massart, Bordet, Gabritschewsky, and others, it is certain that the collecting of the cells is in part due to *chemotaxis*—i.e., by an attraction exerted by substances

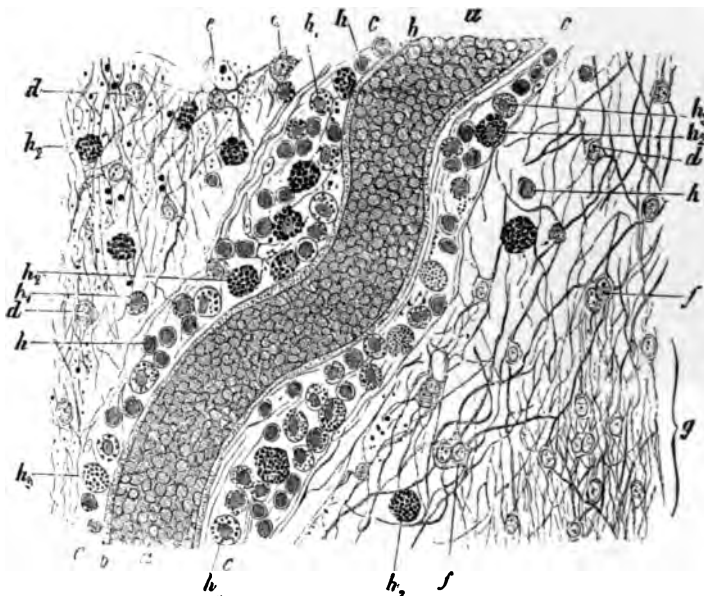


FIG. 218. Granular cells in a focus of degeneration in the brain (teased preparation treated with osmic acid). *a*, Blood-vessel with blood; *b*, media; *c*, adventitia with lymph-sheath; *d*, unchanged glia-cells; *e*, fatty glia-cells; *f*, glia-cells with two nuclei; *g*, sclerotic tissue; *h*, round-cells; *h*<sub>1</sub>, round-cells with few fat-droplets; *h*<sub>2</sub>, fat-droplet spherules; *h*<sub>3</sub>, pigment-granule spherules.  $\times 300$ .

which have been dissolved out of the foreign body or the tissue-detritus; but without doubt other factors may determine the place where the cells collect.

If the material while still undissolved comes within the neighborhood of the motile cells, it is very often taken up by the latter, and there occurs that phenomenon which is known as **phagocytosis**. If the process be observed under the microscope—as may very easily be done by mixing the richly cellular tissue-lymph of the frog with granules of soot—one sees that the mobile cells pour their protoplasm around the foreign bodies and through the union of the pseudopodia extended over the bodies receive them wholly into their protoplasm. Among the foreign bodies which penetrate from without are particularly the different *forms of dust* (especially soot) which are taken into the lungs with the inspired

air, also *bacteria* which are very frequently taken up by leucocytes or by tissue-cells. It is to be noted, however, that a phagocytosis of bacteria does not occur in all infections, but is rather confined to especial infections, and even in these does not occur in all stages of the local disease.

Of tissue-detritus there occur most frequently *fat-droplets* (Fig. 218, *h*, *h*), and disintegration-products of red blood-cells (*h*), and these may be taken up in such abundance by the cells that the latter may become entirely filled with them and become changed into large spherical forms, which have been designated *fat-granule cells* and *pigment-granule spherules*. Besides fat and blood-pigment other tissue-elements—as, for example, fragments of the contractile substance of muscle, or of elastic fibres, or of fibrin—are taken up by cells. The cells which take up such substances are chiefly proliferating tissue-cells—fibroblasts, osteoblasts, sarcoblasts, etc. If an inflammatory exudation runs its course at the same time, and if the proliferating tissue contains *leucocytes*, they may also be taken up by the *phagocytes* (Fig. 219, *a*, *b*, *c*).

**Phagocytosis** is a vital phenomenon of the cells which primarily has for its aim the **taking-up of food**; and it cannot be doubted that in inflammatory foci this aim is in part fulfilled. This is particularly the case in the taking-up of leucocytes by fibroblasts, sarcoblasts, etc.; one can at least see clearly how the leucocytes (Fig. 219, *a*, *b*) within the cells undergo a progressive disintegration (*c*, *d*, *e*) and finally are wholly destroyed. How far other corpuscular elements serve as food-material is dependent upon the chemico-physical properties of the same. This is possible, for example, in the taking-up of fragments of contractile mus-



FIG. 219.—Phagocytes from granulation tissue with included leucocytes and fragments of same (sublimite, Blond's stain). *a*, Round. *b*, spindle fibroblast with leucocytes; *c*, *d*, *e*, fibroblasts containing remains of leucocytes.  $\times 500$ .

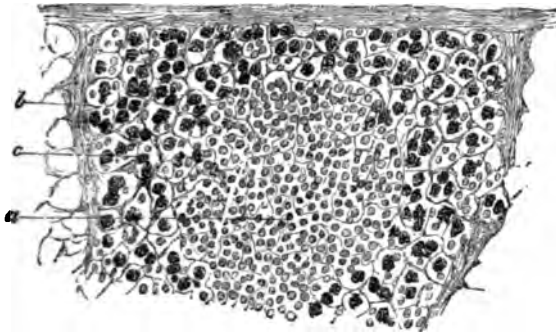


FIG. 220.—Collection of pigment-granule spherules in a lymph-gland (alcohol, carmine). *a*, Lymph-node; *b*, trabecula of the lymph-gland; *c*, lymph-sinus with pigment-granule spherules.  $\times 80$ .

cle substance, fibrin, and of bacteria which are either dead or die within the cell. In other cases such a nutritive process may be excluded, as in the case of insoluble dust. In the case of bacteria it may also happen that these are destroyed, but on the other hand they may multiply, and the resulting bacterial colony causes the death of the cell.

The cells filled with *foreign bodies* are at first found in that place where the phagocytosis occurs, but they may wander further and often pass into the *lymph-channels* (Fig. 218, *c*) and *lymph-glands* (Fig. 220), and further into the *blood-vessels*, whence they are deposited, particularly in the spleen, bone-marrow,

and liver (see § 20 and § 21). Other cells may reach the body surfaces, and the tissues may in this way be cleared of impurities.

If the **foreign bodies** which have penetrated into the body from without, or if the **dying or necrotic portions of tissue** are too large to be taken up by leucocytes or proliferating tissue-cells, there often develop, in the granulation tissue formed in their neighborhood, **multinuclear giant-cells**, which arrange themselves on the surface of the foreign body or of the superfluous tissue-mass (Fig. 221, *d*), in exactly the same manner as is the case with osteoclasts under physiological conditions. If the bodies are not too large they may be taken up by these multinuclear cells. Otherwise the cells remain clinging to the surface, and, if the substance is soluble, gradually bring about its dissolution (for example, catgut sutures, fragments of dead muscle-fibres). Occasionally it happens that mononuclear cells take up small foreign bodies into their substance, and afterward through division of their nuclei become converted into multi-

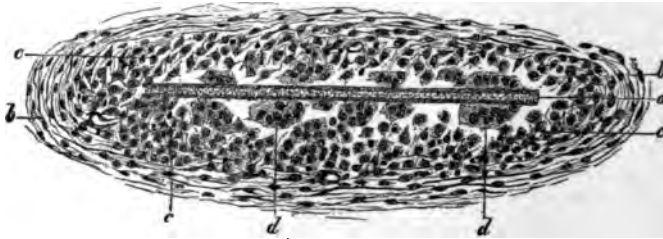


FIG. 221.—Dog's hair encapsulated in the subcutaneous tissue (alcohol, Bismarck brown). *a*, Hair; *b*, fibrous tissue; *c*, proliferating granulation tissue; *d*, giant-cells.  $\times 66$ .

nuclear cells. This event is most frequently observed after the taking-up of bacteria (leprosy, tuberculosis) which continue to multiply within the cells.

If a **foreign body** lying within the tissues cannot be absorbed, it becomes surrounded by granulation tissue, which later changes into connective tissue (Fig. 221, *b*, *c*), and in this manner becomes **encapsulated**. In the case of smooth, insoluble bodies (glass beads) the proliferation may be very slight.

The phenomena of **chemotropismus** or **chemotaxis**—that is, the attraction or repulsion of freely motile cells by chemical substances soluble in water—were first observed by *Strahl* and *Pfeffer*, who made researches particularly on myxomycetes, infusoria, bacteria, spermatozoa, and zoöspores. Investigations by *Lebert*, *Massart*, *Bordet*, *Borissou*, *Gabritschewsky*, and others have shown that the leucocytes may also be attracted by chemical substances (*positive chemotropismus* or *chemotaxis*) or repelled (*negative chemotropismus*). There are in particular products of the vital activity of the fission-fungi (*Lebert*, *Massart*, *Bordet*, *Gabritschewsky*), or bacterial proteids—i.e., albuminoid bodies of dead bacterial cells (*Buchner*)—which even after great dilution (according to *Buchner*, the protein of pyocyaneus is active when diluted 1:300) show a positive chemotaxis. According to *Buchner*, this property belongs also to gluten casein from wheat-paste, legumin, bone-glue, alkali-albuminate from peas, while ammonium butyrate, trimethylamin, ammonia, leucin, tyrosin, urea, and skatol exhibit negative chemotaxis.

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See also § 97; and for further literature concerning the behavior of body-cells toward bacteria, see Chapter X.; and for further literature concerning the fate of transplanted living tissue, see § 88.

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**V. Chronic Inflammations.**

§ 99. Inflammation is, according to its nature, an acute process, but various conditions may cause the phenomena of tissue-degeneration and exudation to persist for a longer time, and the inflammation becomes chronic.

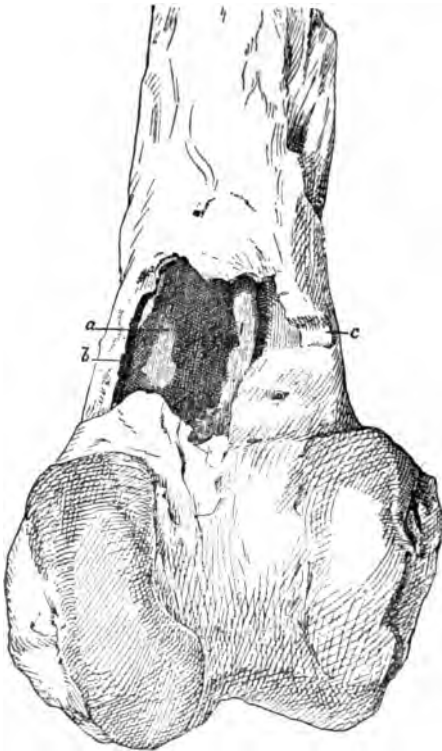


FIG. 222. —Necrosis of fifteen years' duration in the lower part of the diaphysis of the femur. *a*, Sequestrum; *b*, *c*, edges of the opening in the thickened bone (alcoholic preparation). Reduced one-third.

The **causes of chronic inflammations** may be found, in the first place, in the fact that *in the course of an acute inflammation there occur changes which prevent a rapid healing*. In this sense, as may be deduced from the foregoing, act all large tissue defects and tissue necroses, as well as large masses of exudate which are with difficulty absorbable. When necrotic masses of tissue are not completely absorbable, as in the case of large pieces of bone, they may indeed become sequestered, but persist as sequestra for years (Fig. 222, *a*), and keep up a constant inflammation. Following the production of a large, superficial defect of the skin as a result of a burn, there develops a granulation tissue, but months may pass before the wound surface is covered over with epithelium from the edges and the process thereby brought to a close.

A further cause of chronic



inflammation is found constantly in *repeated injury by external influences*. For example, the frequently repeated inhalation of dust may cause chronic inflammation of the lungs; repeated rubbing of the skin may cause a chronic inflammation of the part affected; pathological alterations of the stomach contents may cause chronic inflammation of the stomach. In the canals of the body in which *concretions* may form, the latter may give rise to lasting tissue-lesions.

When there exist in a tissue *unfavorable nutritive conditions*—i.e., marked congestion—these may enable slight external influences, that under normal conditions either produce no inflammation at all or one soon subsiding, to set up ulcerative processes showing no tendency to heal. In this manner, for example, chronic ulcers of the leg may arise.

A very frequent cause of chronic inflammation is furnished by *infections*, particularly those caused by *bacteria* and *moulds*, which multiply in the body and thus constantly give rise to new inflammatory irritation. The inflammations which they cause are distinguished from others chiefly by the fact that they usually show a *progressive character*, and form metastases through the lymph- and blood-vessels.

Finally, *chronic intoxications* form a last cause. These affect chiefly the kidneys and the liver, and may be attributed either to the continued introduction into the organism through the gastro-intestinal tract, lungs, or skin of substances harmful to the organs directly concerned or to others; or injurious sub-

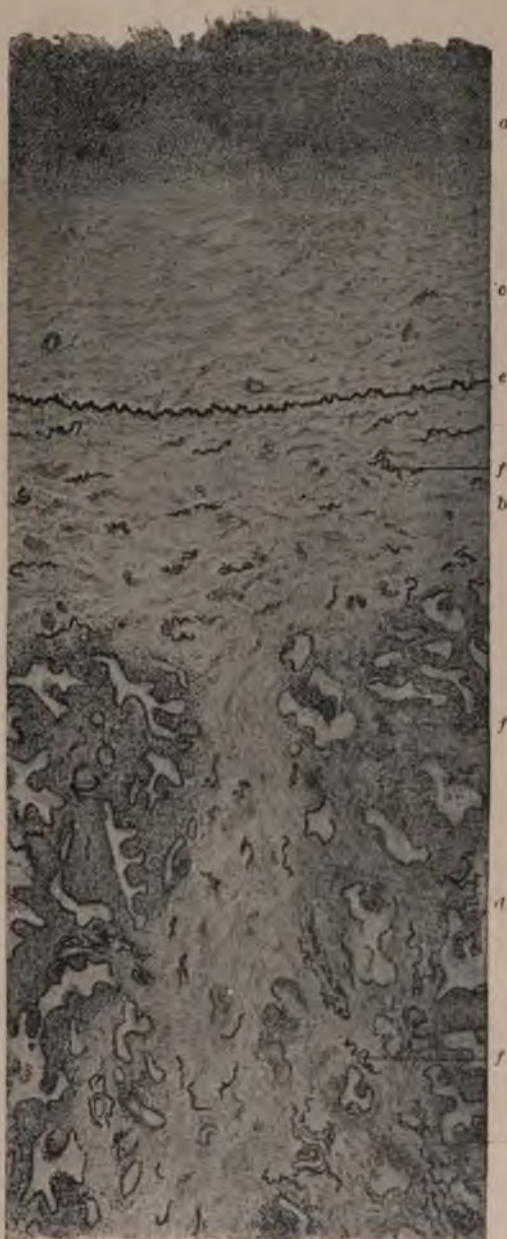


FIG. 222.—Changes in the pleura and lung after a purulent pleuritis lasting six months (alcohol, orcein). *a*, Thickened lung tissue with gland-like alveoli, and elastic fibres in the newly formed connective tissue; *b*, thickened pleura; *c*, newly formed connective tissue without elastic fibres; *d*, granulation tissue covered with pus; *e*, elastic limiting membrane of the pleura; *f*, elastic fibres.  $\times 40$ .

stances may be produced within the body itself, through disturbances of the processes of metabolism, thus giving rise to a *chronic auto-intoxication*.

The **forms of chronic inflammation** are determined partly by their fundamental causes, partly by the character of the affected tissue.

Chronic inflammations characterized especially by **hyperplastic formations of connective tissue** are found especially in the serous mem-

branes, lungs, and external skin, but may occur also in other tissues. Chronic pleuritis, caused by exudates which are with difficulty absorbable, or by chronic infections, lead to extensive *scar-like thickenings of the pleura* (Fig. 223, b, c), the new-formation of tissue occurring in part upon the pleura (c) and in part within it (b). Moreover, *induration of the lung* (a) may follow various *infectious inflammations*, or may be caused by the continued *inhalation of stone dust*, in the latter case being characterized by the formation of



FIG. 224.—Section of a stonecutter's lung with fibroid nodules (alcohol, picrocarmalum). a, Group of fibroid nodules; b, normal lung tissue; c, thickened lung tissue still containing bronchi, vessels, and a few alveoli.  $\times 9$ .

fibroid nodules (Fig. 224, a), in part also by diffuse induration (c). Continued irritation in the neighborhood of the orifices of the urogenital apparatus, as through the discharge of irritating secretions, leads frequently to the formation of *pointed condylomata* (*condylomata acuminata*)—i.e., to a hyperplasia of the papillae and epithelium, in which the inflamed and infiltrated papillae grow out with their vessels (Fig. 225, a, b) and frequently divide into branches.

Frequently repeated or continued slight inflammations of the skin and subcutaneous tissue, due to mechanical lesions, parasites, or any other continued irritation, may also, if they reach a considerable extent, give rise to a diffuse hyperplasia of connective tissue, which is known as *elephantiasis*.

Inflammatory proliferations of the periosteum and bone-marrow, which give rise to *pathological new-formations of bone* or a *hyperostosis* (Fig. 226), may be caused both by non-specific irritations—for example, by inflammations which run their course in the neighborhood of chronic ulcers—as well as by specific infections—for example, syphilis or tuberculosis.



FIG. 225.—Condyloma acuminatum (injected preparation). a, Enlarged branching papillae; b, epidermis.  $\times 21$ .



**Chronic catarrhs** of the mucous membranes are sometimes caused by specific infection (gonorrhœa, tuberculosis), sometimes by non-specific injuries (concretions, pathological changes in the gastric or intestinal contents), and sometimes by continued disturbances of circulation (congestion).

**Chronic abscesses** arise usually from acute abscesses, and have the same etiology as the latter; but may also develop more gradually and are then caused by special infections, most frequently tuberculosis and actinomycosis. They are usually limited externally by a connective-tissue membrane covered with granulation tissue, and may increase in size partly through the secretion of pus from the abscess-wall, and partly through the destruction of the wall and the neighboring tissue. Progressive enlargement toward the deep-lying parts leads to the formation of **burrowing** or **congestive abscesses**. Their increase in size is always to be ascribed to the persistence of the infection. Perforation into neighboring tissues leads accordingly, also, to new infective inflammations.

The tuberculous and actinomycotic forms of chronic abscesses are distinguished from other forms partly by the specific characteristics of the pus and partly by the peculiar structure of the abscess-membrane (see Tuberculosis and Actinomycosis, Chapter X.).

**Chronic ulcers** are caused chiefly by specific infections (tuberculosis, syphilis, glanders), but non-specific injurious agents may lead to chronic ulcerative processes in tissues which are especially susceptible to such changes. Thus chronic congestion in the vessels of the leg may have such an effect that ulcers arising through any mechanical influence may be prevented from healing under the unusual conditions in which the leg finds itself. Likewise peculiar qualities of the stomach contents may hinder the healing of an ulcer of the stomach. If healing begins at one edge of an ulcer while the ulceration advances at other parts, there arises the form of ulcer known as *serpiginous*. The excessive development of granulation tissue in an ulcer leads to the production of an *ulcus elevatum hypertrophicum*; a dense callous, lardaceous thickening of the edge and base gives rise to the form known as *ulcus callosum*, or *indolens*, or *atonicum*.

**Chronic proliferations of granulation tissue**—i.e., granulations which persist as such for a longer or shorter time without becoming changed into connective tissue—occur chiefly in various **specific infections**, the best known being *tuberculosis*, *syphilis*, *leprosy*, *glanders*, *rhinoscleroma*, and *actinomycosis*. Since the granulations in these infections often form



FIG. 226.—Periosteal hyperostosis of the tibia, at the base of a chronic ulcer of the leg. Reduced two-fifths.

fungoid proliferations and tumor-like formations, they are often also called **fungous granulations** or **caro luxurians** and **infectious granulation tumors** or **granulomata**. All these show certain peculiarities which enable us to recognize, from the structure, origin, and life-history

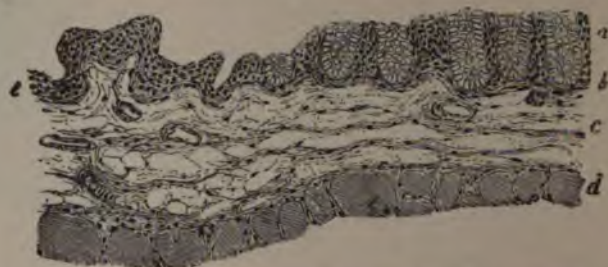


Fig. 227.—Section through the mucosa of an atrophic large intestine (alcohol, alum-carmin). *a*, Glandular layer decreased to one-half its normal height; *b*, muscularis mucosae; *c*, submucosa; *d*, muscularis; *e*, total atrophy of the mucosa.  $\times 30$ .

of the granulation-formation, also its specific etiology (see Chapter X.). It should be noted, however, that the etiology of some of the granulomata developing in the skin is still unknown.

**Chronic inflammations** in which **atrophy of the specific tissue** is

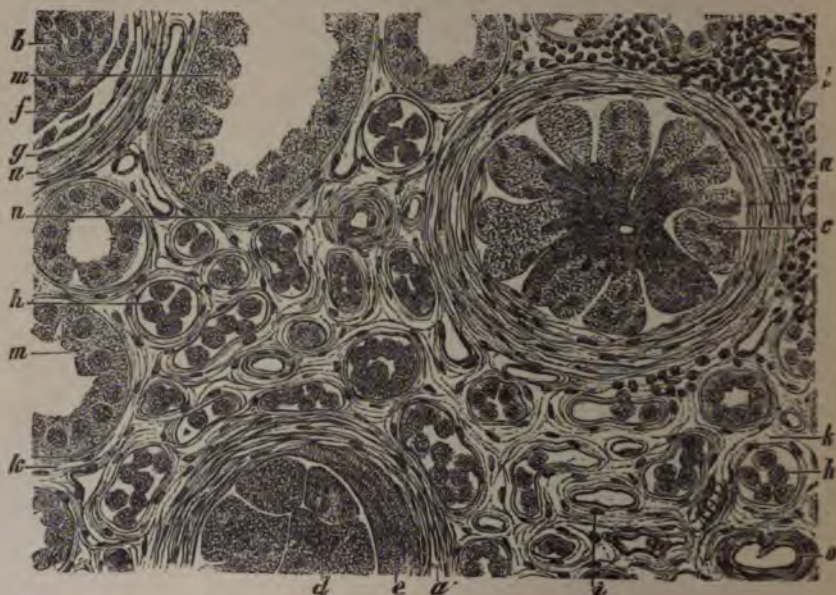


Fig. 228.—Induration and atrophy of the renal tissue in chronic nephritis (alcohol, alum-carmin). *a*, Thickened and fibrous capsule of Bowman; *b*, normal glomerular vessels; *c*, glomerulus whose vascular loops are in part impermeable and homogeneous, and the epithelium for the greater part lost; *d*, completely obliterated glomerulus; *e*, homogeneous masses of coagulation, arising from exudate and desquamated epithelium, and studded with nuclei; *f*, desquamated glomerular epithelium; *g*, capsular epithelium; *h*, collapsed urinary tubule with atrophic epithelium; *i*, collapsed tubule without epithelium; *k*, hyperplastic connective-tissue stroma; *l*, cellular foci; *m*, normal, somewhat dilated tubules; *n*, afferent vessel; *o*, vein.  $\times 250$ .

associated with **hyperplasia of the connective tissue**, occur particularly in the mucous membrane of the gastro-intestinal tract, and in the kidneys and liver.



In the **intestinal canal** the cause may lie in specific (dysentery) as well as in non-specific irritations; the latter being dependent upon some abnormal property of the contents of the canal. The epithelial elements may undergo necrosis in association with persistent desquamation, the connective tissue being unaffected; or they may necrose and disintegrate at the same time with the connective tissue upon which they rest. The final result is a mucous membrane (Fig. 227) which either contains no glands (*c*) or only rudimentary ones (*a*).

In the **liver** and **kidneys** the chronic inflammations which lead to atrophy and induration, and whose final results are known as **cirrhosis of the liver** and **indurated contracted kidney**, are hæmatogenous diseases, in so far as they do not depend upon disturbances in the efferent

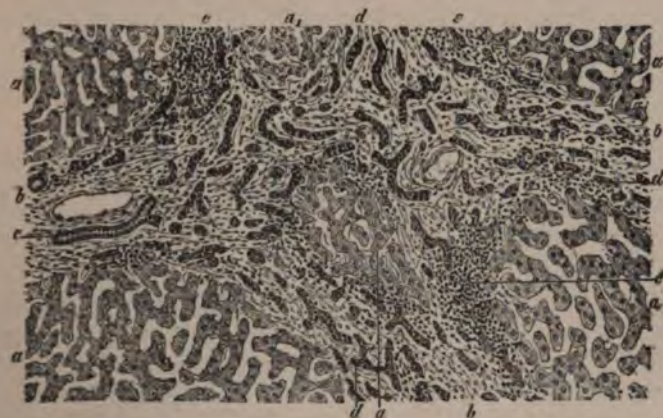


FIG. 229.—Connective-tissue hyperplasia and proliferation of bile-ducts in chronic hepatitis (alcohol, hæmatoxylin). *a, a1*, Liver-lobules; *b*, hyperplastic periportal connective tissue; *c*, old bile-ducts; *d*, newly formed bile-ducts; *e*, foci of small-celled infiltration.  $\times 55$ .

passages (obstruction, formation of concretions), and are caused partly by *infections* and partly by *intoxications*. They may begin either as acute inflammations or more insidiously; and are characterized by atrophy and degeneration of the glandular tissue (Fig. 228, *h, i*), hyperplasia of the connective tissue (Fig. 228, *a, k*, and Fig. 229, *b*), through cellular infiltration, formation of granulation tissue (Fig. 228, *l*, and Fig. 229, *e*), through obliteration of old vessels (Fig. 228, *c, d*), and through the formation of new vessels. In the liver there occurs also very frequently a formation of new bile-ducts (Fig. 229, *d*), which, however, for the greater part do not functionate.



## CHAPTER VIII.

### Tumors.

#### I. General Considerations.

§ 100. A **neoplasm**, or **autonomous new-growth** (Thoma), or **tumor** in the narrower sense, is a *new-formation of tissue, apparently arising and growing independently, having an atypical structure, inserted uselessly into the organism, possessing no function of service to the body, and showing no typical termination to its growth.* The atypical character of the structure of a tumor is shown in its external appearance as well as in its internal organization in that a true tumor departs more or less in structure from that of a normal organ. When this departure is but slight, the structure of the tumor approaches closely to that of the **tissue-hypertrophies**; and there occur cases in which the difference in structure is so little that it becomes very difficult to decide whether an excessive new-growth of tissue is to be classed as a tumor or an hypertrophy.

**Tumors** may develop in any tissue of the body which is capable of growth, and **arise through the proliferation of the tissue-cells**, associated with a **new-formation of blood-vessels**. Not infrequently there occurs also an *emigration of leucocytes* into the tumor, and exudative processes and inflammatory tissue-proliferations may take place in its neighborhood, but these phenomena form no essential part of the development of the tumor.

The processes of cell-division and new-formation of blood-vessels are the same as those described in §§ 81 and 83—i.e., the division of the cells takes place by karyomitosis, and the new vessels are formed from buds given off by the proliferating cells of the walls of old vessels. The mitoses are for the greater part typical (Fig. 230, *b*), but there are also found relatively often atypical forms, such as asymmetrical divisions, nuclear figures with abnormally large chromatin masses (so-called giant mitoses), pluripolar mitoses, and forms of nuclear fragmentation, and also direct segmentation.

In their fully developed condition tumors are for the greater part well defined *from the surrounding tissues*, but in some cases *they may pass into the neighboring tissue without any sharply defined border of transition.* Further, *an entire organ may become transformed into a tumor, or large portions of tissue not sharply outlined from their surroundings may take on the character of a tumor.* Through the disintegration of tumor tissue there very frequently arise *ulcers*.

The difference between the structure of a tumor and that of normal tissue is usually recognizable even macroscopically, but there are also tumors which so closely resemble the parent tissue from which they arise that the difference can be made out only through a more careful examination.

The *circumscribed tumors* are usually **nodular** (Figs. 231, *d*; 233, *d, e*; 234, *a*). The size of the single nodules varies, according to the kind of

tumor and the stage of development at the time of examination, from the smallest visible miliary and submiliary nodules to masses weighing ten to twenty kilograms or more. When situated upon the surface of an organ nodular tumors not infrequently take on the form of a sponge (Fig. 231, *d*) or of a polyp, and are accordingly designated *fungoid* or *polypoid tumors*. When a new-growth on the surface of a mucous membrane or the skin leads to an enlargement and branching of the papillæ there present, or if new papillæ are formed, there arise *warty*, *verrucose*, and *papillary tumors* or *papillomata* (Fig. 232). A further development of the papillary structure may lead to a *dendritic branching* and the formation of a *cauliflower* mass.

Tumors usually develop from small beginnings; only rarely do they arise from centres extending diffusely throughout an entire organ. Their

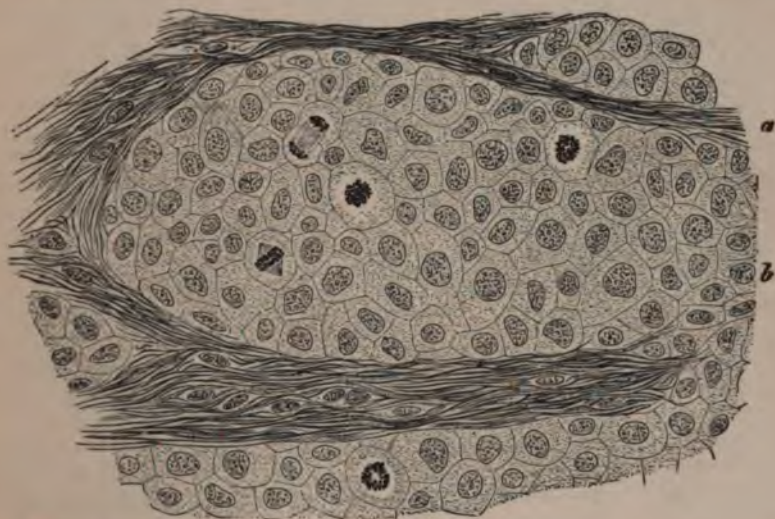


FIG. 230.—Tissue from a carcinoma of the breast, containing numerous division-figures in different phases of mitosis (Flemming's solution, safranin). *a*, Stroma; *b*, epithelial plugs.  $\times 500$ .

growth may be either rapid or slow, and with occasional periods of quiescence. Their growth may be suspended for years, and then suddenly again they become active.

The **structure of the tumor** is determined by the parent tissue from which it takes its origin; and although the true tumors always show a certain *atypical character*, they yet retain certain characteristics of the parent tissue.

According to their structure and genesis tumors may be divided into three groups: 1, *connective-tissue tumors*; 2, *epithelial tumors*; 3, *teratoid tumors and cysts*. It should be noted, however, that there are many forms of tumors which, according to the point of view, may be classed as belonging to two, or even to all three groups.

The **connective-tissue tumors** or the **tumors arising from the supporting-tissue substances**, and which are often called *histoid tumors*, consist of tissues which in their structure correspond in part to mature and in part to embryonal connective tissue of the mesoderm, and moreover take their origin from mesodermal connective tissues. Ordinarily there

are also included in this group those tumors arising from the specific elements of the nervous system—glia-cells and ganglion-cells—since these in their structure resemble the connective-tissue tumors much more than they do the epithelial.

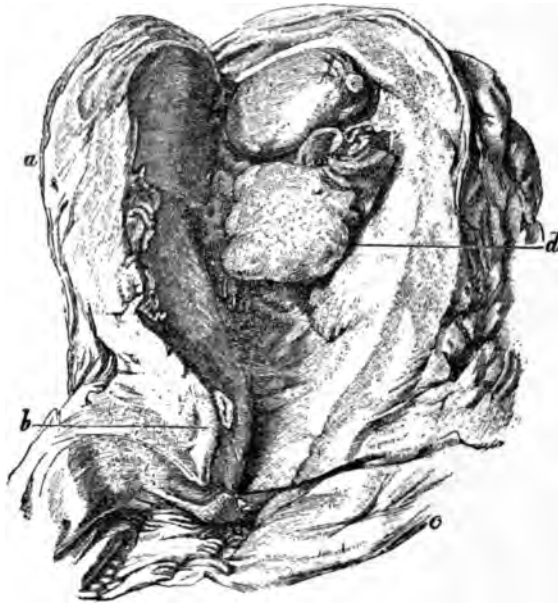


FIG. 231.—Fungoid carcinoma of the endometrium of the posterior wall of the uterus. *a*, Body of the uterus; *b*, cervix; *c*, vagina; *d*, tumor. Two-thirds natural size.

surface epithelium or from *gland-cells*, and also of *vascular connective tissue*—which forms a supporting framework in the spaces of which the cells arising from the proliferation of surface epithelium or gland-cells lie in definite groups. Inasmuch as this arrangement gives to the tumors a structure suggesting that of a gland, they are often also called *organoid tumors*, in contradistinction to the histoid connective-tissue tumors. It should be noted, however, that there are also included in the connective-tissue group of tumors certain varieties (*sarcomata*) which have an organoid structure.

The cells which give the epithelial tumors their especial character arise either from the ectoderm or endoderm, and from the glands developing from the same, or finally from the mesodermal epithelium of the pericardium, and of the pleural and peritoneal cavities, or of the glands arising from this layer (kidneys, sexual glands, adrenals). Tumors having the last-named origin often show more or less distinctly the especial character of the parent tissue from which they arise.

Very soft cellular epithelial tumors are also designated *medullary*.

The differences in the types of the connective-tissue tumors are essentially dependent upon the character of the ground-substance, and in part also upon the cells. When the tumors are very rich in cells and the ground-substance but slightly developed, they acquire a soft consistency and are classed with the *sarcomata*. Very soft forms are designated as *medullary* or *fungi medullares*. Through the combination of different forms of connective tissue there arise *mixed connective-tissue tumors*.

The **epithelial tumors** are composed of cells derived from *sur-*



FIG. 232.—Papillary adenoma of rectum. Natural size.

Combinations of epithelial proliferations with proliferations of the connective tissue, which exceed the ordinary amount of supporting tissue or bear a sarcomatous character, lead to the formation of *epithelial mixed tumors*.

The **teratoid tumors and cysts** form a group which is especially characterized on the one hand by the fact that they contain the most varied kinds of tissue which may be derived from all three germ-layers (*teratoid mixed tumors*), and on the other hand by the presence of tissue formations in regions where they do not normally occur. Tumors, therefore, which according to their structure may be placed in one of the other groups, may be considered as teratomata on account of their situation. Further, there are also included in the group of teratoid tumors certain formations which according to their structure, origin, and physiological relations ought not to be classed with the tumors.

**Tumors** usually develop **singly**; but it also happens that within a certain tissue system there may appear either coincidently or in succession a **great number of tumors of the same kind**, so that it must be assumed that the conditions requisite for the development of these tumors were present in different parts of the system affected. At times there develop in different organs of the *same* individual two *entirely different varieties of tumors*, which stand in no relation to each other, and whose coincident appearance is purely accidental.

The exact determination of what should be included under the term **tumor** is hardly possible; and consequently the designation tumor is applied to many different formations which, according to their etiology, genesis, and life-characteristics, have not the same significance. The idea of tumor is, therefore, very differently conceived by different authors. I regard it as advisable, and also as based upon the life-characteristics of the tissue-formations which we are about to consider, to exclude in the first place from the class of tumors all hyperplastic proliferations, and further all retention-cysts which arise purely through the retention of secretions and show no independent new-formation of tissue. Further, according to my view, *there should be separated from the true tumors all proliferations of tissue due to the presence of parasites or to infection*, particularly the infectious granulomata which occur in tuberculosis, syphilis, leprosy, etc. Should it be proved—which so far has not been done—that some of the new-growths now included with the true tumors are caused by infection, they should also be excluded from the category of true tumors.

The above **classification of tumors** is based essentially upon their histological character and histogenesis. They may of course be classified according to other points of view. *Lubarsch* has offered the following classification with reference to the growth and behavior of the tumor: (1) Tumors which differ from the parent tissue in the arrangement of their elements, but for the chief part present no recognizable increase or at most only a transitory growth (various teratoid new-growths, misplaced tissue anlage, congenital nevi, many adenomata, myomata, fibromata, lipomata, chondromata, and osteomata); (2) tumors which show a certain autonomy and independence in their structure, but yet on the whole obey the normal laws of life in that they always respect the physiological tissue boundaries (myomata, adenomata, angiomata, lipomata); (3) tumors which are wholly emancipated from the physiological laws of life and rule in the tissues in total lawlessness of growth (carcinoma, sarcoma).

The **atypical structure of tumors** is not given so much prominence by all authors as has been done above. This is particularly true with reference to those tumors which are similar in structure to the parent tissue from which they arise, and which are accordingly designated *homoplastic tumors*. It should be noted, however, that even in these tumors (chondroma, osteoma, fibroma, etc.) there occur in general, both in the histological structure, coarser organization, and external form, pronounced departures from the normal; and, moreover, it may also happen that inflammatory proliferations caused by infection may show a structure similar to that of tumors. It is therefore not always easy to determine positively whether a new-growth is to be regarded as a tumor.

**Tumors are in no sense useful** to the organism as many tissue-hypertrophies may be. Tumor tissue does not possess the specific activity of that tissue from which

it springs, so that tumors can in no way be regarded as useful new-formations of tissue. It happens, indeed, that in certain tumors there occur **processes of secretion** which correspond to normal secretions—thus, epithelial tumors may produce mucous or horny or colloid material (thyroid tumors), or bile-pigment (liver-tumors), even in metastatic nodules—but from these facts we can conclude only that, in many tumors which do not differ too greatly in structure from the parent tissue, the cells may retain, to a certain degree, for a number of generations, the functional capacities of the parent tissue. There is, however, no basis for believing that new useful tissue is formed as in the case of hypertrophy from increased labor; the products are for the chief part of no use to the body, and though perhaps in especial cases the colloid or bile so produced may be made use of, such a function must surely be of much less value than that of the normal tissue.

The tumors arising from the mesodermal epithelium of the serous membranes or of the glands arising from these are included in the **group of epithelial tumors**. This is justified by the fact that such tumors correspond in their structure and clinical behavior to the epithelial tumors of the ecto- and endoderm. I have also considered the question whether it would not be advisable (as *Hansemann* has proposed) to class also among the epithelial tumors—i.e., the adenomata and carcinomata—those tumors which have a framework of connective tissue, the spaces of which are filled, in a manner suggesting epithelial tissues, with cell nests arising from the proliferating endothelium of the blood- and lymph-vessels. Aside from the similarity in the structure of these tumors with the ordinary adenomata and carcinomata, there may be taken in favor of this view the fact that from the anatomical side the endothelium of the blood- and lymph-vessels is often designated as mesodermal epithelium. Against such a grouping of the endothelial with the epithelial tumors may be urged the facts that, aside from the general acceptance of the term endothelioma, the behavior of the endothelium of the blood- and lymph-vessels under pathological conditions is very different from that of epithelium, and that in many tumors it is impossible to separate the products of the growth of the endothelium of the blood- and lymph-vessels from the products of proliferation of connective-tissue cells.

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 See also §§ 101 and 102.

§ 101. The **etiology of tumors** is by no means uniform, and very often cannot be determined with certainty. In the majority of cases, however, the *conditions*, at least, under which the new-growth appeared can be assigned and we may accordingly establish different groups of tumors. *Infection* is indeed very frequently advanced as a cause of tumors, but such etiology has not in any case been demonstrated beyond doubt.

*As the first group of tumors, according to etiology, may be taken those arising from especial congenital Anlage, so that we may in a certain sense regard them as local malformations of tissue.* They develop either in uterine life, and are present at birth, or later in extra-uterine life, during the period of growth or even later, in which case trauma not infrequently gives the immediate occasion for the beginning of the development of the tumor from the preëxisting Anlage.

To this group belong in the first place many osteomata, chondromata, angiomata, gliomata, fibromata (of the nerves and skin), sarcomata and adenomata. Further, many teratoid tumors and cysts are also to be included in this group, inasmuch as they represent in part either remains of fetal structures, transpositions or monogerminal inclusions of embryonic tissue, implantations of rudimentary portions of a twin embryo (bigerminal implantations), or probably also the results of disturbances of the earliest stages of the development of the ovum.

*A second group develops after traumatic injuries of the tissues*; and it has been reckoned that in about seven to fourteen per cent of cases a traumatic origin can be assigned; particularly in the case of sarcoma, carcinoma, and osteoma. The causes of the tumor-formation may be a single injury, a stab, a blow, crushing, fracture, etc., as well as repeated mechanical irritation, such as rubbing, scratching, etc.

*In a third group the development of the tumor follows inflammation, particularly the formation of granulation tissue with subsequent cicatrization.* The inflammation and ulceration may be caused by non-specific as well as by specific injurious agents. For example, cancer of the gall-bladder (Fig. 233, d, e) almost invariably develops only in gall-bladders which contain

stones, and are consequently the seat of chronic inflammation. In the stomach, cancer may develop in the edge of an ulcer or in the scar of one after healing has occurred. In the external skin and also in the mucous

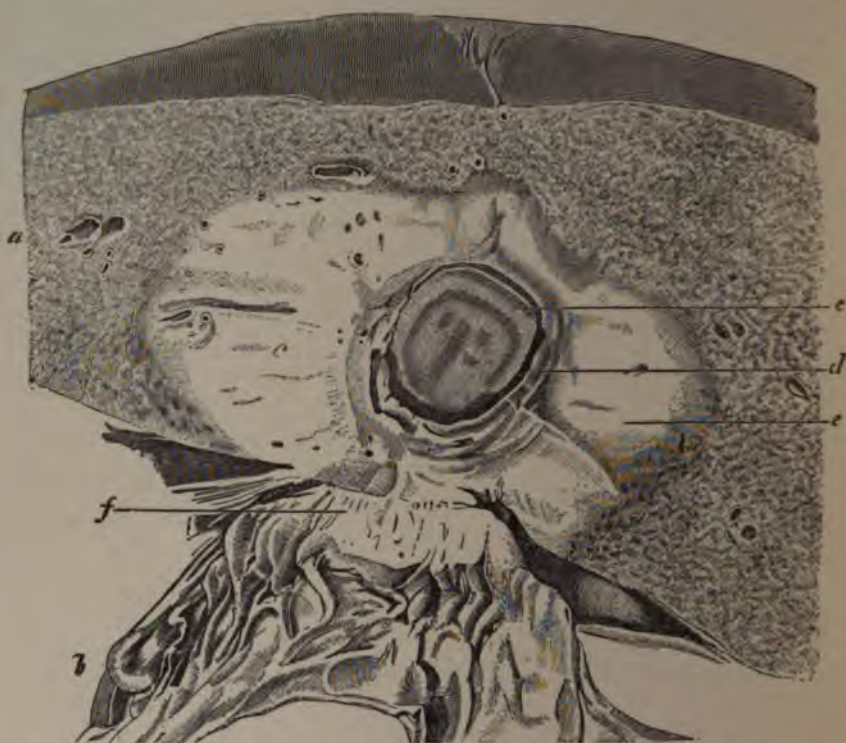


FIG. 233.—Primary carcinoma of the gall-bladder enclosing an impacted gall-stone. Frontal section through the gall-bladder and liver. *a*, Liver; *b*, duodenum; *c*, gall-stone; *d*, wall of the carcinomatous gall-bladder; *e*, cancerous infiltration of the neighboring liver tissue; *f*, portion of duodenum which is infiltrated with cancer and adherent to the gall-bladder tumor. Natural size.

membranes of the pharynx and larynx cancers occasionally arise in the base of a tuberculous or syphilitic granuloma or in the scar of such a process.

*In a fourth group the development of the tumors appears to owe its origin to an unequal atrophy of the elements which make up a tissue, so that certain hindrances to growth are removed or lessened. Here belong especially certain epithelial proliferations (cancers) which develop in old age, or in organs which after a period of increased activity become atrophic. In this way, for example, the development of cancer of the skin may be explained on the ground that the connective tissue of the skin undergoes a certain retrogression leading to a relaxation of its structure, while the epithelium is still possessed of its full power of proliferation.*

It cannot be doubted that the **etiology of tumors** is not always the same, as is shown by the variety of conditions under which they arise.

It is difficult to say what is the nature of the influence which excites the cells to the *production of an atypical tissue*. We are at first inclined to think of the same causes which underlie hypertrophy and regeneration of tissue, also, on the one hand, of especial congenitalanlage or of stimuli which increase the formative activity of the cells.

and on the other hand, of a lessening or removal of hindrances to growth. But it still remains a problem why there should not be formed typical tissues which would so fit into the organization of the body that they would be of service to the latter. In the attempt to explain this phenomenon, which is at the same time associated with an increase in the vital and reproductive capacities of the cells, even under pathological conditions (metastasis of the cells through the blood- and lymph-vessels), many writers have sought and would recognize as the cause the presence of *parasites* (see Etiology of Carcinoma); but our present knowledge does not in any way justify us in attributing the development of true tumors, of autonomous new-growths, to the influence of parasites. On the contrary, the development and life-history of tumors, and in particular the formation of metastases, which without doubt arise through the multiplication of living tumor-cells transported in the lymph- or blood-stream, speak against the hypothesis of the parasitic nature of tumors.

*Cohnheim* advanced the theory that all true tumors arose from especial tumor-anlage which had their origin in the persistence of foci of embryonal tissue. Neither the results of clinical observation nor of the anatomical investigation of the tissues speak in favor of such a theory.

*Ribbert* is of the opinion that the cause of the pathological proliferation which leads to tumor-formation is to be found particularly in a separation of cells or cell-groups from their organic relations, such a separation occurring either as the result of intra-uterine disturbances of development or later under the influence of external agencies. Nevertheless, such transplantations or separations of cell-groups take place very frequently in intra-uterine life, or after trauma, after ulceration, in scars and in infectious granulomata, without any subsequent development of a tumor. These transplantations of tissue constitute only one of the predisposing causes of tumor-formation, but some other factor is necessary to excite the atypical progressive tissue-proliferation—i.e., the development of the tumor. The development of a tumor is, therefore, in no wise dependent upon a transplantation of tissue; rather does the tumor-proliferation take its origin in cells which are normally situated; and this may be actually demonstrated, particularly in the case of epithelial tumors.

Our knowledge of the causes of tumor-development at the present time may be summed up as follows: Inherited and acquired conditions of certain cells and cell-groups, which assert themselves in a tendency to increased formative activity with the production of atypical tissue, lead to the formation of tumors. In many cases this proliferation is prepared for, favored, and excited by the transplantation of cells and cell-groups, but often also through changes in the neighborhood of the cells concerned. No general scheme applicable to the development of all tumors can be given. On the contrary, the conditions vary not only with the different forms of tumors, but also with the individual cases of the same tumor-type. Moreover, it should not be forgotten that the formations which we class as tumors do not all possess the same significance, and that many of the same ought more properly to be classed with other phenomena of growth (malformations).

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See also § 100.

§ 102. When once a **tumor** has arisen in any tissue and has reached a certain stage of development it **may become quiescent in growth**, and remain for a life-time without undergoing further change. This is true particularly of those tumors which according to their origin are regarded as *local tissue-malformations*; but tumors which develop first in later life may also come to a standstill after attaining a certain size.

The **growth of a tumor takes place independently**, and in many cases continues even until death occurs.

From the surrounding tissues the tumor **acquires both its blood-vessels and thereby its food material**, but **may besides grow independently**—i.e., through an increase of the cells which form the elements of the tumor. In many cases the tumor increases in size **essentially through an**



**interstitial expansive growth**, and the neighboring tissue is only crowded or pushed aside. In other cases the **tumor tissue grows by infiltration** and *forces its way into the intercellular spaces of the neighboring tissue*, so that new areas of tissue are thus brought under the influence of the tumor. In this way the cells of the newly invaded tissue are often excited to proliferation, so that an enlargement of the tumor takes place through an *appositional growth*, in which both the cells of the original tumor and of the surrounding tissue take part.

The characteristic feature of **growth by infiltration** consists in the *involvement of the tissues of the organ which lie in the neighborhood of the primary tumor*. Further, the *tissue of neighboring organs* (Fig. 233, e, f)

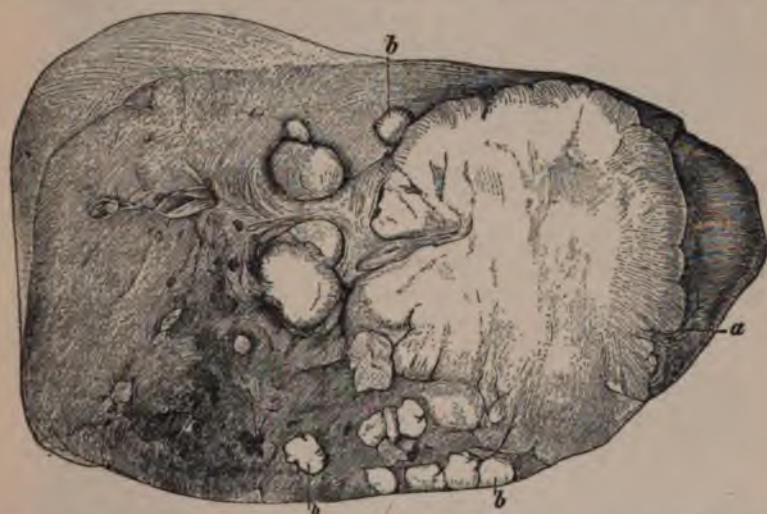


FIG. 234.—Section through a primary cancer of the liver (a), with multiple metastases (b) within the liver itself. Three-sevenths natural size.

*may become involved by the tumor through its spread by contiguity. If tumor-cells gain entrance into the great body-cavities they may spread over the serous surfaces and lead to the development of tumors.*

If, in the process of infiltration, a tumor *gains entrance into a lymph- or blood-vessel*—an event which in particular is always likely to occur in the case of the tumors called carcinoma and sarcoma—and *if living tumor-cells capable of proliferation* are transported through the lymph- or blood-vessels, there often arise **tumor-metastases**—i.e., a development of **daughter-tumors** which are not directly connected with the primary tumor. The daughter-tumors may at first develop in the organ primarily affected (Fig. 234, b), but usually soon involve other organs as well; in the case of rupture into the lymph-vessels the *lymph-glands* are first affected; in rupture into the blood-vessels, *those organs to which the blood carries the living cells*. The direction of the transportation is usually that of the lymph- and blood-stream, but retrograde transportation not infrequently occurs, particularly in the lymph-vessels, the lumina of which are easily obstructed by tumors.

The development of daughter-tumors takes place in all cases from **transported cells**. In the event of **metastasis by the lymph-vessels** the affected lymph-vessels (Fig. 235, a) are first filled with cells, which



develop from the transported tumor-cells. Later there follow a proliferation and new-formation of blood-vessels on the part of the neighboring tissue, and as a result of these processes there develop larger or

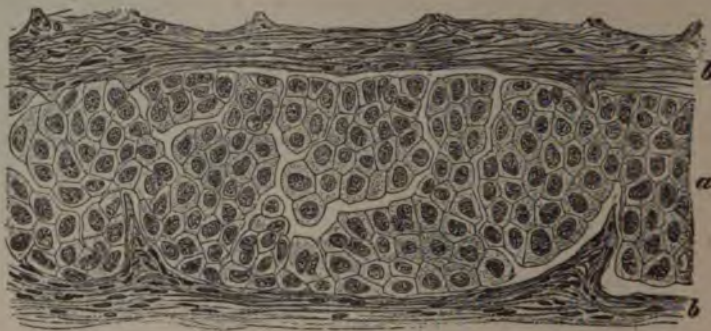


FIG. 235.—Periglandular lymph-vessel (in the axillary region) filled with cancer-cells arising from a primary carcinoma of the mammary gland (Müller's fluid, hæmatoxylin). *a*, Cancer-cells; *b*, wall of lymph-vessel.  $\times 300$ .

smaller *nodules*. It also not infrequently happens that the *lymph-vessels* are more uniformly distended by the growth (Fig. 235, *a*), without any real formation of nodules, or at least only small swellings develop along the course of the lymph-vessels. In the event of metastasis into *lymph-glands*

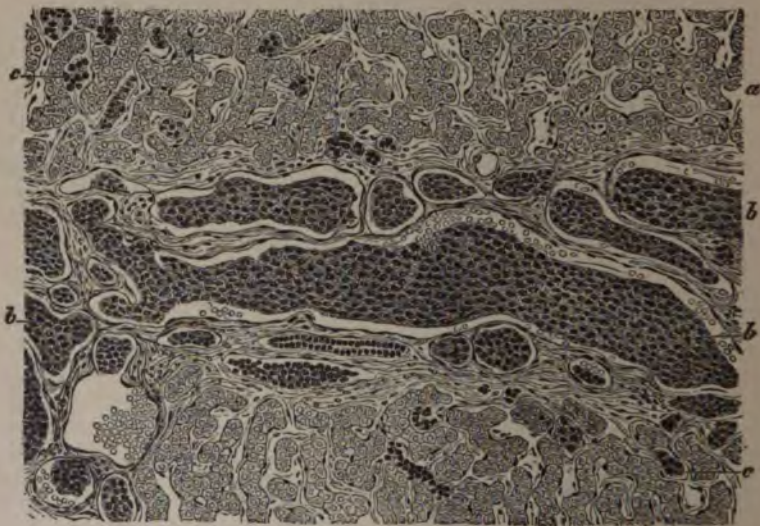


FIG. 236.—Metastatic development of cancer in the branches of the portal vein and liver-capillaries (Müller's fluid, hæmatoxylin, and eosin). *a*, Liver tissue; *b*, plugs of cancer-cells in the portal vein; *c*, cancer-cells in the capillaries.  $\times 100$ .

the latter become swollen, forming *nodules* of smaller or larger size, in which the tissue of the lymph-gland is gradually replaced by tumor tissue.

In the case of **metastasis through the blood-vessels** the first development of the secondary tumor begins with the tumor-cells forming the em-

bolus in artery, capillary, or vein, and under certain conditions the vessels (Figs. 236, *b, c*; 237, *b, c*) may be filled and greatly dilated by the proliferating tumor-cells. The tissue in which the tumor-embolus develops may at first remain passive, and the specific tissue-elements—gland-cells (Fig. 237, *d*) and muscle-cells—may vanish as the result of increasing atrophy. Later, the blood-vessels and connective tissue take part in the development of the secondary tumor.

In the further course of its development the secondary nodule is usually sharply circumscribed from its surroundings and grows by expansion. It, however, not infrequently happens that, at least in places,

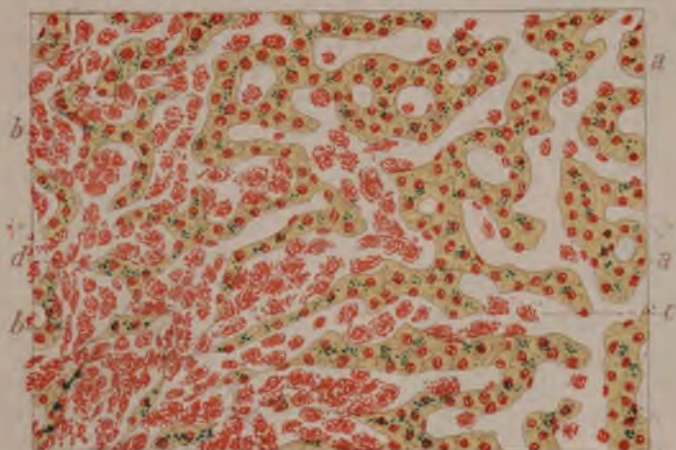


FIG. 237.—Metastatic sarcoma of the liver from a primary sarcoma of the parotid (Flemming's solution, safranin, picric acid). *a*, Liver-rods; *b*, sarcoma tissue developing within the vessels; *c*, isolated tumor-cells in the liver-capillaries; *d*, liver-cells which have undergone atrophy and fatty degeneration.  $\times 150$ .

the infiltrative growth persists, and under certain conditions widespread diffuse tumors develop, particularly in the bone-marrow and in the liver (Fig. 237).

The number of lymphogenous and hæmatogenous metastases varies greatly in different cases. At one time the metastases may be confined to one organ, at other times they may be scattered throughout several. In rare cases cells of the original tumor may be spread through almost the entire body, so that in the most diverse organs—glands, muscles, skin, etc.—larger and smaller nodules may appear in quick succession. This phenomenon is possible when tumor-nodules situated in the lung, pleura, or bronchial glands break into a pulmonary vein.

If a living bit of tumor capable of forming metastases is transplanted from one animal into the tissues of another animal of the same species, it sometimes happens that it will develop in the second animal. There may take place, therefore, a *metastasis from one animal to another*. In man, tumor particles may in a similar manner be transplanted during operations from one part of the body to another and there continue to grow.

Side by side with the progressive proliferation of tissue there very frequently occur in tumors **retrogressive changes**, particularly in rapidly growing and infiltrating cellular tumors, in which fatty and mucous degeneration, necrobiotic processes, and hæmorrhages may take



place to a marked degree, so that there not infrequently results a total *destruction of the tumor tissues*. This rapid disintegration of the tumor is in part due to the fact that in carcinomata the epithelial proliferation to a very great extent grows into the blood-vessels and so obstructs them. In the case of nodular tumors the destruction of the tumor-cells, when followed by a resorption of the products of degeneration, leads to *shrinking* and to the formation of *cicatricial contractions*. Very often *degeneration-cysts* and *ulcers* may be thus formed; and particularly in the case of carcinomatous tumors of the mucous membranes the parts of the tumor growing up above the surface very often for the greater part undergo disintegration. In slowly growing tumors of hard consistency extensive retrograde changes do not usually occur.

The necrosis and disintegration of the tissues of the tumor only very rarely terminate in a *cure*. This event is most likely to happen when a polypoid new-growth becomes totally necrotic (for example, as a result of twisting or tearing of its pedicle) and is thrown off. In the majority of the tumors showing a tendency to retrogressive changes and disintegration, while the older portions are dying the growth constantly advances at the periphery, so that new tissues are being progressively attacked by the tumor.

If the **tumor is extirpated**, there may result a *cure* when all of the growth has been removed or destroyed. This is most easily accomplished in the case of slowly growing and sharply circumscribed tumors which increase by expansion. In the case of infiltrating tumors it is very difficult to determine the boundary of the tumor-growth, since this may often extend far beyond the point where any macroscopic change in the tissue is apparent. Consequently, in such cases there takes place, sooner or later, in the operation scar a **recurrence** (Fig. 238, *a*) which arises from portions of the tumor remaining in the tissues. Such recurrences behave exactly like the primary tumor, and may also form metastases (Fig. 238, *c*).

According to their clinical and anatomical characteristics **tumors** may be classed as **benign** and **malignant**. As *benign tumors* are generally regarded those which grow slowly and by expansion and do not form metastases; as *malignant*, those which show a complete emancipation from the normal laws of proliferation, grow quickly and by infiltration, easily undergo degenerative changes and form metastases. According to the investigations of Brault, the cells of rapidly growing tumors are rich in *glycogen*; in those of slow growth, and after the inception of retrogressive changes, it is absent.



FIG. 238.—Recurrent sarcoma in the amputation-stump of the femur. *a*, Fungoid tumor arising from the bone-marrow; *b*, periosteal nodules; *c*, metastasis. One-half natural size.

The **malignant tumors**, on the whole, coincide with those tumor forms which are known as *carcinoma* and *sarcoma*. It must, however, be borne in mind that the malignancy of a tumor depends not only upon its character, but also upon its location. A benign tumor takes on a malignant character as soon as its presence interferes with the functions of vital organs. Hence every tumor of the brain or meninges becomes a dangerous affection at the moment when it gives rise to disturbances of the cerebral functions. Under certain conditions such benign tumors as fibromata of the uterus become destructive growths as soon as they reach such a size as to displace and compress the neighboring organs.

After a tumor has existed for a certain period there results very frequently a marked lowering of the general nutrition, a *marasmus*, which is usually designated **tumor-cachexia**. This occurs chiefly in association with the malignant growths known as cancer and sarcoma; and may depend, in part at least, upon the great demands made upon the food supply by the rapid growth of the tumor, particularly in the case of formation of metastases. A still more important cause may lie in the fact that the tumor may interfere with the taking-in of food. In cancer of the œsophagus, stomach, and intestine the function of the affected organ is greatly interfered with, and the assimilation of food may be entirely prevented or nearly so. Further, it should be borne in mind that through the degeneration of the tumor and the continuous secretion from the resulting ulcers large amounts of albuminous material may often be lost from the body; and that through putrid decomposition there may arise substances which, when absorbed, may act injuriously upon the organism. Finally, the pain which is often felt in a tumor may rob the patient of his sleep. Whether the tumor itself, in certain cases, produces substances harmful to the organism is yet unknown, but is, however, not improbable.

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## II. The Different Forms of Tumors.

### I. TUMORS DERIVED FROM CONNECTIVE TISSUE OR THE SUPPORTING FRAMEWORK.

#### (a) *Fibroma.*

§ 103. A **fibroma** is a tumor composed of *fibrous connective tissue*. It occurs most frequently in the form of *nodules*, which are sharply circumscribed from the surrounding tissues, and usually involve but a portion of the affected organ. Very rarely an entire organ may become changed into a single tumor-mass. On a free epithelial surface and on mucous membranes a fibroma may appear in the form of a *papilloma*.

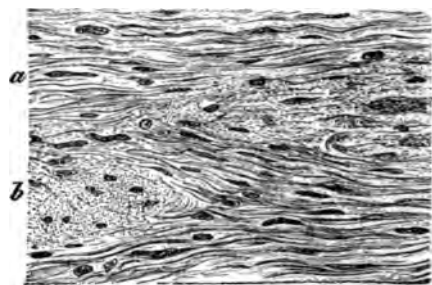


FIG. 239.—Hard fibroma from lobe of the ear (alcohol, hæmatoxylin). *a*, Longitudinal section; *b*, transverse section of bundles of fibres.  $\times 400$ .

According to the character of the connective tissue of which it is composed, the consistency of a fibroma may vary greatly. Often it is *hard and tough*, creaking under the knife (*desmoid*), and showing on its cut surface a white, tendon-like, shining tissue; but in other cases the growth may be soft, flaccid, the cut surface being more uniformly grayish-white and somewhat translucent. In still other cases the individual strands of connective tissue are indeed white and shining, but the tumor as a whole has a looser structure and is correspondingly flaccid.

Between the hard and soft growths there exist all possible transition-forms, and even in one tumor different parts may possess different characteristics.

Under the microscope the hard kinds appear to be composed chiefly of thick bundles of coarse fibres (Fig. 239, *a*, *b*), in which lie scattered a larger or smaller number of cells. In the softer forms the bundles of fibres are more delicate (Fig. 240, *a*). If as a result of venous congestion or other cause a clear

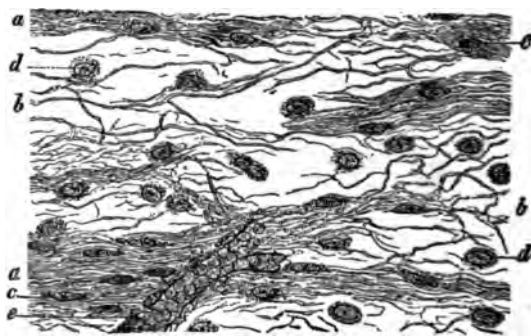


FIG. 240.—Section of an oedematous fibroma of the uterus (osmic acid, glycerin). *a*, Closely lying fibres; *b*, fibres pressed apart by fluid; *c*, spindle-shaped cells; *d*, swollen round cells; *e*, blood-vessel.  $\times 200$ .



fluid collects between the fibrillæ, there is formed an *œdematous fibroma*, whose bundles of fibres (Fig. 240, *b*) are pressed apart by the fluid, the tissue becoming softer and more moist and translucent, and finally resembling the tissue of the umbilical cord.

The *soft forms of fibroma*, which present a partly translucent, grayish-white cut surface, are usually very rich in cells; so that it is possible by teasing to isolate numerous small spindle-shaped cells (nuclei with



FIG. 241.—Fibroma pericanalliculare mammae (Müller's fluid, alum carmine, eosin). *a*, Gland-tubules; *b*, newly formed pericanallicular connective tissue rich in cells; *c*, connective tissue poor in cells.  $\times 55$ .

tails). The intercellular substance is correspondingly less in amount, the fibrillæ more delicate and arranged in finer bundles. Sections through such fibromata, when stained, appear very rich in nuclei (Fig. 241, *b*).

Fibromata develop from proliferating connective-tissue cells, and it is usually possible to find in the tumor certain areas which are richer in cells than the main mass of the tumor tissue, and in which the cells appear not only as small spindle cells, but also in part as round cells, or as short, thick spindles, or even as stellate cells. The transformation of the newly formed cellular tissue into connective tissue takes place in the same way as that described under Hyperplasia of Connective Tissue. A new-formation of elastic fibres is usually wanting, but at times such a new-formation does occur, particularly in the neighborhood of the blood-vessels.

Fibromata may appear in any part of the body which contains any form whatsoever of connective tissue. They occur most frequently, for example, in the nerves, skin, periosteum, fascia, uterus, and mucous membrane of the nose; more rarely in the ovary, mammary gland, intestinal tract, etc. In the mammary gland the development of the fibroma takes place particularly around the canaliculi (Fig. 241, *b*), so that the latter come to be surrounded by connective tissue rich in cells.

Fibromata do not form metastases, but often occur as multiple tumors, especially in the nerves and skin (see Neurofibroma, § 112).

Moreover, it is not uncommon to see within a tumor several centres of growth—that is, the mass of the tumor is made up of several nodules or bands held together by ordinary connective tissue (Fig. 241, *b*). Fibromata are malignant only through their size and position.

Fibromata may undergo fatty degeneration or may soften and disintegrate, so that cavities may be formed within them. They may also break through and give rise to ulcers. Their blood-supply varies greatly, at times being scanty, at other times abundant. Occasionally the blood-vessels are ectatic, so that the tissue is interspersed with wide channels and clefts, from which blood escapes when the tumor is examined in a fresh state. In other cases dilated lymph-channels are seen.

**Keloid** is the designation applied to a hard, nodular, or flat and banded, or stellate growth of the skin, which in its fully developed state consists of dense fibrous tissue without elastic fibres. The direction of the fibres is often at right angles to the surface of the skin, or at least does not accord with that of the normal fibres. It usually develops after injuries or inflammations (*cicatrix-keloid*), but it may also appear without such association (*spontaneous keloid*). The cause of the keloid growth is not known; the tendency to recurrence after removal, the multiple occurrence, and the fact that many cases frequently occur in the same family (Hutchinson) speak in favor of a special predisposition on the part of the skin.

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 See also § 112.

#### (*b*) *Myxoma.*

§ 104. A **myxoma** is a tumor which consists essentially of *mucous tissue*, and is made up of cells and a fluid or gelatinous intercellular substance containing mucin. The cells of the tumor are for the greater part polymorphous, with processes of varying length (Fig. 242) which anastomose with one another (Fig. 243, *a*). The tissue is markedly translucent, soft, and the blood-vessels are easily seen through it. From the cut surface gelatinous masses or a stringy fluid, which swell up in water, may be obtained.

No tumor is ever wholly made up of myxomatous tissue; the latter is usually combined with other forms of tissue, particularly with fibrous connective tissue, fat tissue, cartilage, and sarcomatous tissue. For this reason such tumors are properly designated **fibromyxoma**, **lipomyxoma** (Fig. 245), **chondromyxoma** (Fig. 248, *c*), and **myxosarcoma** (Fig. 243).

Mucous tissue may develop from fibrous connective tissue through the collection of a mucin-containing fluid between the fibrillæ and the gradual disappearance of the latter. Adipose tissue may pass over into myxomatous tissue through the disappearance of fat from the fat-cells and the appearance of a mucin-containing gelatinous substance between the cells, during which process the fat-drops become broken up into swollen droplets (Fig. 245, *b*, *c*), while the cells themselves become smaller and star-shaped (*d*). Cartilage may also become transformed into mucous tissue through a mucoid degeneration of the basement-substance and a change of form of the cells (Fig. 248, *c*, *d*). Myxosarcomata (Fig. 243) arise either through a local increased activity of cell-proliferation in myxomata or through a collection of mucoid substance between the sarcoma cells.

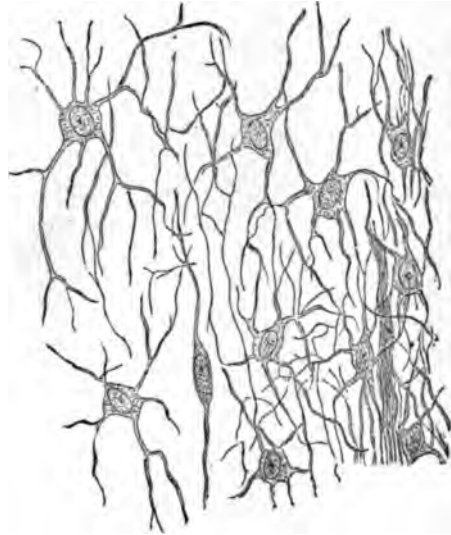


FIG. 242.—Cells from a myxoma of the periosteum of the femur (gold preparation).  $\times 400$ .

Myxomata, myxofibromata, and myxolipomata develop most frequently in the connective tissue of the periosteum, skin, heart, fascia, and sheaths of the muscles, as well as in the fat tissue of the subcuta-

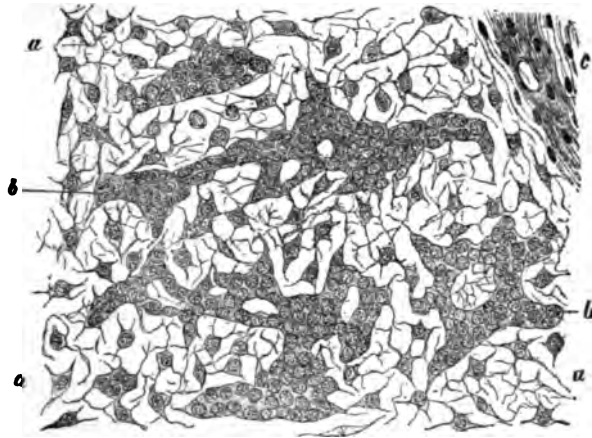


FIG. 243.—Section of a myxosarcoma (Müller's fluid, carmine, glycerin). *a*, Myxomatous tissue; *b*, strands of cells; *c*, fibrous tissue.  $\times 225$ .

neous and subserous tissues and of the bone-marrow. Myxochondromata occur particularly in the parotid, and constitute the most common form of tumor found there.

These forms are all benign tumors, which rarely produce metastases. Myxosarcomata, on the other hand, have the characteristics of sarcomata and may form metastases.

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#### (c) *Lipoma.*

§ 105. A **lipoma** is a tumor consisting of *adipose tissue* (Fig. 244). These tumors are sometimes soft, sometimes firm, usually nodular and lobulated, and very often attain a very great size. In structure they are very similar to the subcutaneous adipose tissue—that is, they consist of fat-lobules held together by thick or narrow connective-tissue trabeculae.

Histologically, the tissue of a lipoma resembles the fat-lobules of the subcutaneous panniculus (Fig. 244), although the tendency to form typical grape-like clusters of fat-cells is wanting. If, as not infrequently happens, mucous tissue is also formed in connection with the fat tissue, or if the latter, following a disappearance of its fat, becomes changed into myxomatous tissue, the tumor is designated a **lipomyxoma** (Fig. 245); if there is an abundance of fibrous tissue present, it is called a **lipofibroma** or **fibrolipoma**.

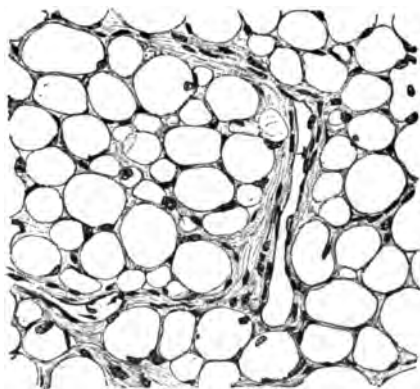


Fig. 244.—Lipoma of shoulder region, with relatively small fat-cells (Müller's fluid, haematoxylin).  $\times 300$ .

Lipomata develop most commonly from adipose tissue, but may arise also from connective tissue which normally contains no fat. Calcification, necrosis, gangrene, and sloughing are of not infrequent occurrence in lipomata of large size. These tumors do not produce metastases, but are occasionally of multiple occurrence. A complete disappearance of a lipoma does not take place in the case of extreme general emaciation of the individual.

Lipomata are sometimes observed even in new-born children—for



example, as tumors developing in or over the cleft-formations of *spina bifida*—but they occur much more frequently in later years. The most common seats of these growths are the subcutaneous tissues of the back,



FIG. 245.—Lipomyxoma of the back (Müller's fluid, Van Gieson's). *a*, Large fat-cells; *b*, *c*, fat-cells in which the fat is broken up into little droplets; *d*, mucous tissue; *e*, blood-vessel.  $\times 300$ .

buttocks, neck, axilla, abdomen, and thigh; but they are found also in the intermuscular connective tissue, subserous fat tissue, in the kidneys, intestine, mammary gland, under the aponeurosis of the forehead, in the meninges, skin, fingers, lymph-glands, joints, etc. They may occur as multiple growths, and in such cases may be symmetrically distributed. In man there occurs a rare formation of fat tissue about the neck and throat, leading to nodular and lobulated disfigurations of the skin of this region, and giving occasion for the designation *fatty collar* (Madelung). The development of fat in these cases takes place partly in the subcutaneous tissue, partly in and under the fascia and between the muscles. An abnormal development of fat in an extremity may give rise to a condition of *lipomatous elephantiasis*. Should the process extend to the trunk and upper extremities, etc., conditions are established which resemble very closely general obesity.

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(d) *Chondroma.*

§ 106. A **chondroma** or **enchondroma** is a tumor consisting essentially of *cartilage*. The amount of connective tissue taking part in the structure of the tumor, in part covering its surface or accompanying the blood-vessels into



FIG. 246.

FIG. 246.—Periosteal chondroma of a digital phalanx, seen in longitudinal section. a, Chondroma; b, phalanx. Natural size.



FIG. 247.

FIG. 247.—Section from a chondroma of the ribs (haematoxylin, carmine). a, Cartilage rich in small cells; b, cartilage rich in large cells.  $\times 80$ .

its interior, is so slight as to fall completely into the background when compared with the cartilage.

Chondromata develop chiefly in those places where cartilage is found normally—that is, in the osseous system or in the cartilages of the respiratory tract; but they also occur in tissues which normally possess no cartilage—for example, in the salivary glands, particularly in the parotid, and in the testicles, and more rarely in other organs. In the bones they develop from remains of cartilage which persist after ossification, in the case of bones developing from cartilage; but more often take their origin from the periosteum and bone-marrow (Fig. 246). They form tumors which vary greatly in size. The small ones are usually spherical (Fig. 246); the larger ones nodular or lobulated. The individual nodules are often separated from one another by connective tissue. Not infrequently they are multiple, particularly in the skeleton, and here again of most frequent occurrence in the hands and feet.

The tissue of an enchondroma presents most often the characteristics of hyaline cartilage (Fig. 247), more rarely that of reticular or fibrous cartilage. At the periphery of the tumor the cartilage passes over into connective tissue, which forms a kind of perichondrium.

The number, size, form, and grouping of the cartilage cells vary greatly in different cases and also in different parts of the same tumor. Many enchondromata are very cellular (Fig. 247), others poor in cells, many contain large cells, others small cells, or both large and small cells.

The cells are sometimes surrounded by the so-called capsule, at other times not; sometimes they lie in groups inside of the mother-capsule, at other times they are more regularly distributed. All the varieties of cartilage occurring normally in the organism are found in enchondromata. Accordingly the cells vary in form, the majority showing the familiar spherical form, but spindle and stellate cells are not rare, particularly in the neighborhood of the connective-tissue bands which divide the tumor into nodules or surround it as a whole. Cartilage, the perichondrium, bone-marrow, periosteum, and different forms of connective tissue may form the matrix of enchondromata. Those arising from cartilage or bone are known as *enchondroses*.

The tissue of enchondromata very frequently suffers retrogressive metamorphoses. Very often a portion of the cells contain fat-droplets. The ground-substance in large tumors shows a tendency to undergo in



FIG. 248.—Chondromyxosarcoma parotidis (alcohol, carmine). a, Cartilage; b, sarcomatous tissue; c, myxomatous tissue; d, cartilage in process of breaking down and being converted into sarcomatous and myxomatous tissue.  $\times 80$ .

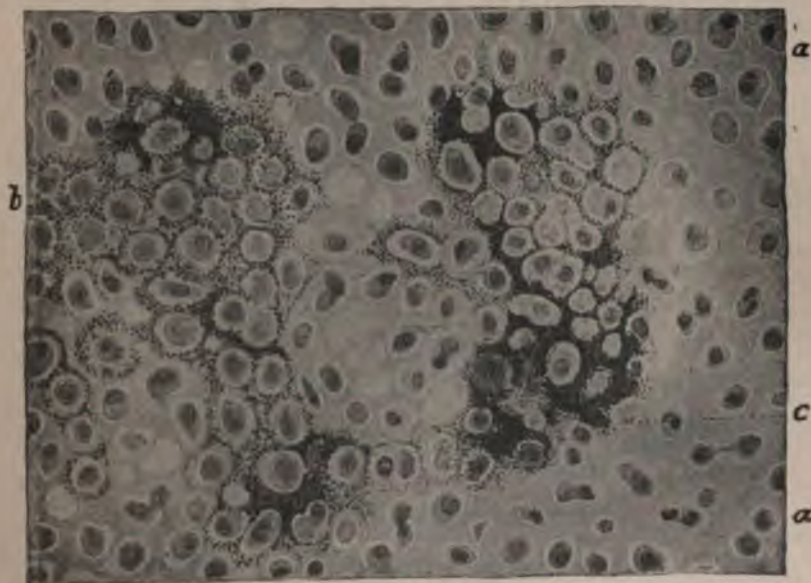


FIG. 249.—Periosteal chondroma of the calcaneus, with areas of calcification (Müller's fluid, haematoxylin). a, Hyaline cartilage; b, c, calcified cartilage.  $\times 225$ .



areas a mucoid degeneration and liquefaction. This may lead either to the formation of *mucous tissue* (Fig. 248, *c*), thus giving rise to a *chondromyxoma*; or to a total liquefaction of the ground-substance with destruction of the cells, thus forming *degeneration-cysts* containing fluid.

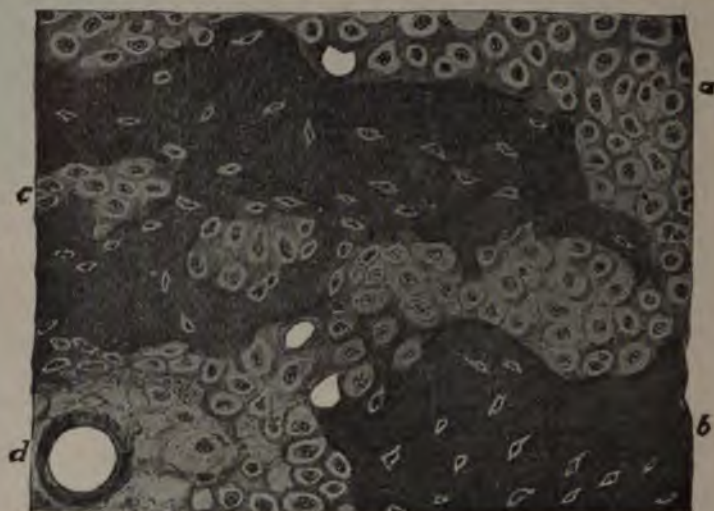


FIG. 250.—Osteochondroma of the humerus (alcohol, picric acid, hematoxylin, carmine). *a*, Hyaline cartilage; *b*, bone; *c*, cartilage which is becoming converted into bone; *d*, blood-vessel.  $\times 250$ .

In other cases the cartilage may become calcified (Fig. 249, *b*, *c*), or true *bone* may be formed (Fig. 250, *c*, *b*), so that the tumor must be termed an **osteochondroma**. Through a marked proliferation of the cartilage cells *sarcomatous tissue* may be developed, the tumor becoming changed to a **chondrosarcoma** (Fig. 248, *b*).

The enchondromata are, on the whole, benign tumors, although metastases may occur following a rupture into a lymph- or blood-vessel.

In the region of the spheno-occipital suture, in the median line of the clivus, there is not infrequently found a small tumor which has been designated **ecchondrosis physalifera sphenooccipitalis** (*Virchow*). It either lies beneath the dura, or at its highest point breaks through this membrane and penetrates into the arachnoid and pia. In its typical form the tumor consists of bladder-like cells, resembling plant-cells; and takes its origin partly from the bone-marrow, partly from the surface of the bone. Cartilage and bone tissue may be associated with the peculiar tumor tissue, and for this reason *Virchow* regarded the growth as a chondroma arising from remains of the spheno-occipital cartilage and characterized by a peculiar vacuolar degeneration of the cells. The peculiar character of the tissue, however, favors the view advanced by *H. Müller*, and recently supported by *Ribbert*, that the growth is a product of a proliferative activity of remains of the chorda (*chordoma*).

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## (c) Osteoma.

§ 107. The term **osteoma** is applied to tumors which consist of *osseous tissue*. Such growths arise chiefly from the bones of the skeleton (Figs. 251-253), but may develop elsewhere.

The new-growths of bone arising in connection with the skeleton have been variously designated according to their location and relations. A small circumscribed new-growth of bone attached to old bone is called an *osteophyte*; when of a larger size and more tumor-like, an *exostosis*. Circumscribed formations of bone inside of bones are known as *enostoses*. New-growths of bone not attached to old bone are classed as follows: *movable periosteal exostoses*, which have their seat in the periosteum but are separated from the bone; *parosteal osteomata*, lying near the bone; *disconnected osteomata*, which are situated some distance from the bone, in the muscles and tendons; and, finally, *heteroplastic osteomata*, which occur in other organs, as, for example, in the lungs, mucous membrane of the trachea, in the skin, mamma, etc.

Excrescences on the teeth, consisting of cement-substance, are known as *dental osteomata*; those consisting of dentine, as *odontomata*.

According to their structure, osteomata may be divided into hard or *eburneous osteomata* (*osteoma durum* or *eburneum*) (Figs. 251 and 253), and softer *spongy forms* (*osteoma spongiosum* or *medullare*) (Figs. 252 and

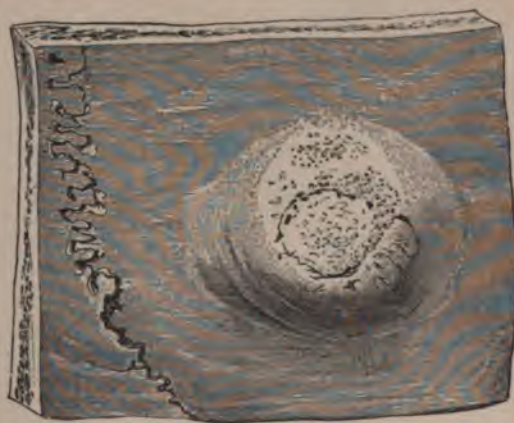


FIG. 251.—Ivory-like exostosis of the parietal bone. Natural size.

254). The former consist of firm, compact tissue like that of the cortical portion of the long bones, and possess very narrow nutrient canals (Fig. 253, *a*); the latter are made up of narrow, delicate bony trabeculae and wide medullary spaces (Fig. 254), and resemble spongy bone in structure.

The surface is sometimes regular and smooth, so that the whole tumor presents the form of a cone (Fig. 251), or of a sphere, or a pedunculated button; or it may be irregular, rough, and nodular, without definite resemblance to any given form (Fig. 252). The first variety occurs particularly in the eburneous forms, which are found most frequently as exostoses upon the skull (Figs. 251 and 253); the latter in the spongy exostoses and the disconnected and heteroplastic osteomata, such as are found, for example, in the falx of the dura mater (Fig. 254).

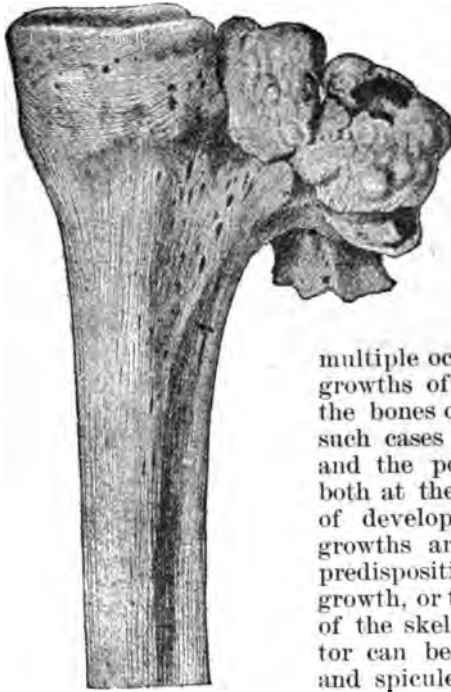


FIG. 252.—Exostosis cartilaginea of the upper diaphysis of the tibia. Reduced about one-half.

Osteomata may occur as *single* or *multiple* tumors, the latter mode of occurrence being relatively common. The ivory-like exostoses of the cranium and the osteomata of the dura mater are very frequently of multiple occurrence, and circumscribed bony growths often appear in great numbers on the bones of the extremities and trunk. In such cases the epiphyseal ends of the bones and the points of insertion of tendons, or both at the same time, are the favorite seats of development. It is probable that such growths are to be referred to an inherited predisposition of the part affected to overgrowth, or to disturbances in the development of the skeleton. At times a hereditary factor can be demonstrated. The bony plates and spicules, which in rare cases develop in the lung or in the mucous membrane of the air-passages, may also occur in large numbers.

The development of the bone takes place partly through the formation of osteoblasts, as described in § 84, and partly through metaplasia of formed tissues (§ 89). The matrix is formed chiefly from the connective tissue of the periosteum, as well as that of the tissue from which the osteoma arises; and also from the cartilage and bone-marrow. If an exostosis develops in such a manner that cartilage is first formed from the proliferating periosteum or bone-marrow, and from this cartilage bone is later developed, it is called a *cartilaginous exostosis* (Fig 252); when the exostosis is formed directly from the proliferating periosteum without an intermediate stage of cartilage, it is known as a *connective-tissue exostosis* (Figs. 251, 253, and 254).

The combination of connective tissue and bone in a tumor, in such a manner that the connective tissue represents a chief constituent of the growth and does not simply represent the periosteum and bone-marrow



of the bone, gives rise to an **osteofibroma**. This is a very common tumor of the osseous system. The abundant production of bone in a



FIG. 253.—Ivory-like osteoma of the parietal bone, seen in frontal section. *a*, Osteoma; *b*, skull-cap. Eight-ninths natural size.

chondroma leads to the formation of an **osteochondroma** (Figs. 250 and 255); these tumors are likewise usually found in the long bones. The



FIG. 254.—Osteoma of the dura mater (alcohol, picric acid, hæmatoxylin, carmine).  $\times 40$ .

new-growth may develop in the periosteum (Fig. 255, *c*) or in the marrow (*a*, *b*). An abundant formation of bony trabeculae (*f*, *h*, *k*) in the cartilage (*e*, *g*, *i*) gives to the tissue a firm, hard consistence.

Many of the new-growths of bone which come under observation are not tumors in the strict sense of the term, but are hyperplasias resulting from excessive growth or from inflammatory processes. This is true

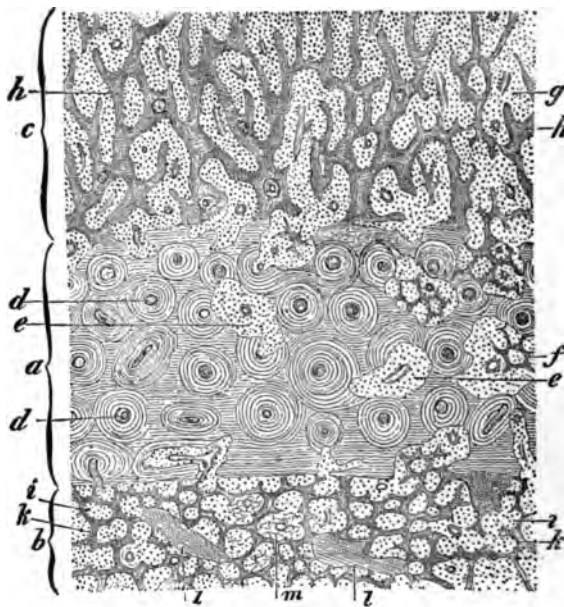


Fig. 255. Osteochondroma of the humerus (alcohol, picric acid, hæmatoxylin, carmalum). *a*, Cortical portion of the humerus; *b*, medullary cavity; *c*, periosteal deposit of bone; *d*, normal Haversian canals; *e*, dilated Haversian canals filled with cartilage, containing newly formed bone at *f*; *g*, cartilage with bone-trabeculae *h*, formed by the periosteum; *i*, cartilage with newly formed bone-trabeculae, arising from the marrow; *k*, *l*, old bone trabeculae; *m*, remains of marrow-tissue. Pocket-lens magnification.

particularly of many osteophytes and exostoses, and also in part of the parostoses and the disconnected osteomata. The bony plates not infrequently found in the falx of the dura, and which have a normal bone-marrow (Fig. 254), are to be regarded as misplaced portions of the skeleton. The formations of bone known as *rider's bone* and *drill-bone*, which are found in the adductors of the thigh and in the deltoid muscle, as the result of riding and the repeated shouldering of arms, are to be regarded as tumors, which develop from a *congenital anlage*, in that the connective-tissue of the muscle shows characteristics

which ordinarily belong only to the periosteum and bone-marrow. The so-called *myositis ossificans*—a peculiar disease of the muscles, characterized by a progressive ossification of their connective tissue during childhood—is to be similarly interpreted.

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(f) *Hæmangioma and Lymphangioma.*

§ 108. Under the term **angioma** are grouped those *tumor-like formations in the structure of which blood-vessels or lymph-vessels constitute such an important part as to determine the character of the tumor.*

Vascular tumors arising from blood-vessels are called **hæmangiomata**, or **angiomata** in the restricted sense of the term; those arising from lymph-vessels are designated **lymphangiomata**. Such tumors for the greater part represent formations which may be regarded as *malformations* of a more or less extensive vascular area. Of the hæmangiomata there may be distinguished four chief varieties: *hæmangioma simplex*, *hæmangioma cavernosum*, *hæmangioma hypertrophicum*, and *angioma arteriale racemosum*.

A **hæmangioma simplex** or **teleangiectasia** is a tissue-formation in which, within a ground tissue of normal occurrence in the body, there is

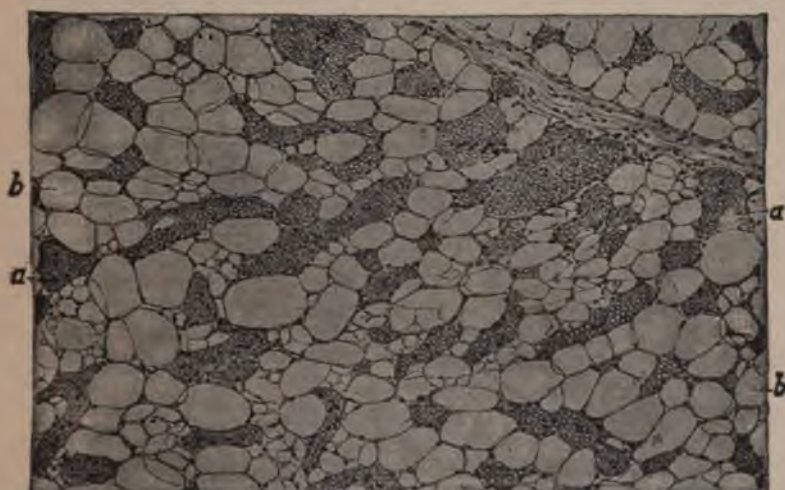


FIG. 250.—Teleangiectasis of the panniculus adiposus of the abdominal wall (formalin, hæmatoxylin, eosin). a, Blood-vessels filled with blood; b, adipose tissue.  $\times 80$ .

found an *abnormal increase in the number or in the size of the capillaries and veins, whose structure in part is essentially changed.*

Such formations occur most frequently in the skin and subcutaneous tissue. They are usually congenital, but increase in size after birth. They are designated **vascular nævi**, and are often found in places



where fetal clefts have closed (*fissural angiomata*). Of a tumor in the ordinary sense it is often scarcely possible to speak, since the skin may show no tumor-like elevation. On the other hand, there occur extensive

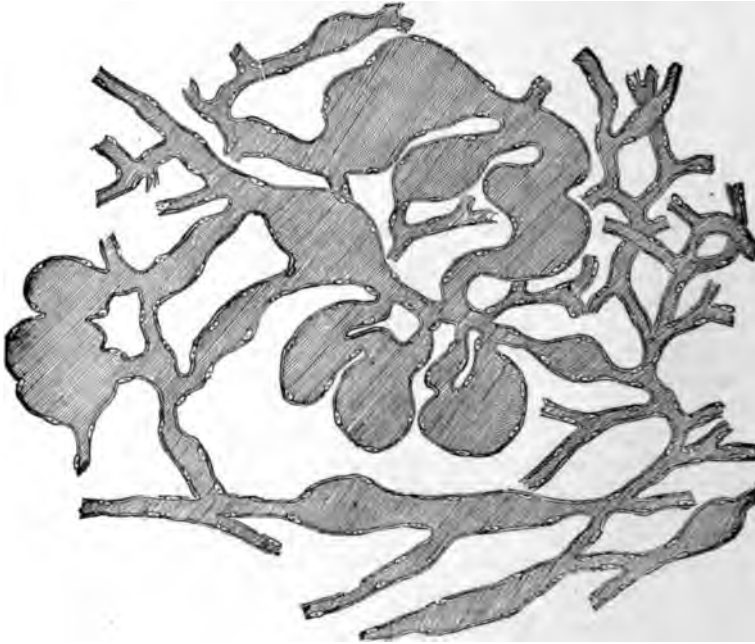


FIG. 257.—Dilated capillaries of a telangiectatic tumor of the brain, isolated from a portion of tumor by means of shaking.  $\times 200$ .

telangiectases of the skin and subcutaneous tissue, presenting either as circumscribed growths or as flat, occasionally nodular thickenings of the skin, which may with propriety be termed tumors. The smooth *naevus vasculosus*, on the other hand, appears as an extensive superficial substitution of the skin by another tissue. The color of the affected portion of the skin is either *bright red* (*naevus flammeus*) or *bluish-red* (*naevus vinosus*). The line of demarcation between the normal and affected skin is usu-

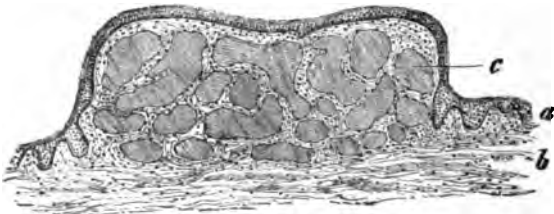


FIG. 258. Angioma cavernosum cutaneum congenitum (Müller's fluid, hæmatoxylin). a, Epidermis; b, corium; c, cavernous blood-spaces.  $\times 20$ .

ally not a sharp one; around the edge and in the neighborhood of the chief area of discoloration there are often found little, circumscribed red spots appearing as outrunners of the process.

The red color is due to the dilated blood-vessels which are situated either in the corium or in the subcutaneous fat tissue (Fig. 256, a); and cases occur in which large areas of the subcutaneous adipose tissue present a red appearance as a result of the pathological development of blood-vessels.

More rarely than in the skin and subcutaneous tissues, there occur similar angiomas in other places: in glands (mamma), bones, brain (Fig. 257), and spinal cord and their membranes. Not infrequently, on the other hand, there are found analogous vascular changes in tumors, as, for example, in gliomata or sarcomata.

If the vessels, which are usually abnormally abundant, are isolated, it becomes evident that the capillaries, or also the small veins (*angioma simplex venosum*), are more or less dilated. These dilatations (Fig. 257) are either spindle-shaped or cylindrical, but may be saccular or spherical, and the different forms of dilatation may be combined in the greatest variety of ways. The dilated blood-vessels are united with



FIG. 259.—Angioma cavernosum hepatis (Möller's fluid, hæmatoxylin, eosin). a, Liver tissue; b, angioma.  $\times 100$ .

each other by capillaries of normal size or of moderately increased calibre. The walls of the vessels are thin—that is, in comparison with normal capillaries they are but slightly thickened.

A **hæmangioma cavernosum** or *tumor cavernosus* is a *vascular tumor consisting essentially of a cavernous spongy tissue*, whose structure suggests that of the corpus cavernosum or spongiosum of the penis (Figs. 244 and 245). Through the filling of the spaces with blood these tumors present a bluish-red or dark red color.

The cavernous angioma, like the angioma simplex, occurs chiefly in the skin (Fig. 258, c) and subcutaneous tissues, where during the period of development it appears as a pathological formation of the vascular system. At times it forms only a small bluish-red spot (*navus vasculosus rinosus*); at other times, a smooth, elevated (Fig. 258), or slightly nodular bluish-red wart (*navus vasculosus prominens, verruca vasculosa*); or, finally, a circumscribed bluish-red discoloration or thickening of the skin. In the event of an extensive development of cavernous tissue in the subcutaneous or intermuscular connective tissue, there may result



large tumors and elephantiasis-like disfigurations of portions of the body (*elephantiasis hæmangiomatosa*).

Within the body the cavernous angioma is found most commonly in the liver (Fig. 259, *a*, *b*), but may develop also in other organs:

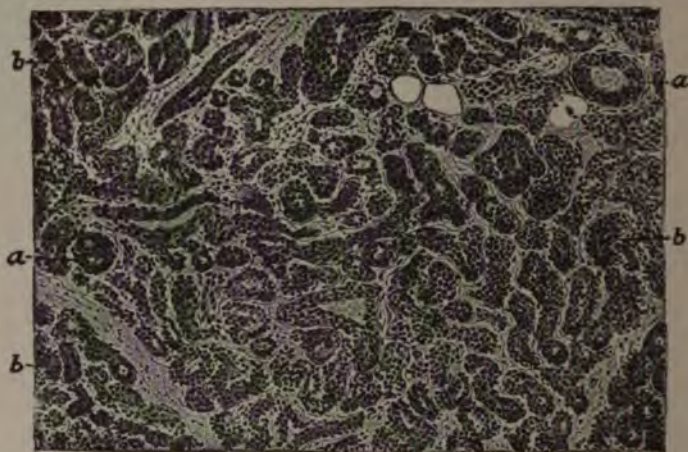


FIG. 260.—Angioma simplex hypertrophicum (formalin, hæmatoxylin). *a*, Vessels containing blood; *b*, empty and collapsed thick-walled blood-vessels rich in nuclei.  $\times 100$ .

kidney, spleen, intestine, bladder, bones, muscles, uterus, brain, etc. In the liver it appears in the form of dark-red areas, varying in size from that of a pin-head to several centimetres in diameter. They take the place of the liver tissue, and are not elevated, or but slightly, above the liver surface.

The width of the blood spaces and the thickness of the trabeculæ vary greatly in different cases; the angioma may in portions or through-



FIG. 261.—Angioma simplex hypertrophicum cutaneum et subcutaneum (alcohol, carmine). In the middle of the section is the duct of a sweat-gland cut transversely.  $\times 200$ .

out be composed of fibrous tissue, in that more fibrous tissue was formed in the beginning, or fibrous proliferations have taken place later as sequelæ to the thrombosis. The blood spaces are lined with endothelium; at times smooth muscle-fibres may be demonstrated in their walls, and the interstitial tissue is often rich in elastic fibres (Brüchanow). The tumor is usually sharply outlined from the neighboring structures by connective tissue. Usually no liver cells are found in the trabeculæ, but varieties do occur in which the latter in part enclose such, and in which, further, the blood spaces here and there pass over into the liver-capillaries, such

a communication ordinarily not taking place.

The cavernous angioma of the liver occurs in old individuals, and also in infants and children of different ages, and not infrequently is of mal-

multiple occurrence. It is probably caused by a local disturbance of development, which (Ribbert, Bruchanow) proceeds from the vessels of Glisson's capsule or from the intra-acinous capillaries (Orth, Schmieden); and is characterized by an abnormal development of the blood-vessels at the expense of the other tissues. The growth is slow and limited; ordinarily the liver-cells in the immediate neighborhood show no signs of degeneration. During the period of rapid growth (Bruchanow), there may occasionally be demonstrated in children the presence at the periphery of the growth of a cellular granulation tissue, in which the blood-vessels consist of delicate endothelial tubes of narrow lumen.

The **hæmangioma hypertrophicum**, in its most typical form (*hæmangioma simplex hypertrophicum*), occurs most frequently in the skin and subcutaneous tissues, where it forms circumscribed nodules similar in part to the soft, smooth warts. The pathologically altered vessels may lie in the papillæ and corium as well as in the subcutaneous tissue, and either form narrow tubes filled with blood (Figs. 260, *a*, and 261), the



FIG. 262.—Angioma cavernosum hypertrophicum (angioendothelioma) of the skull-cap (Möller's fluid, hæmatoxylin). *a*, Blood-vessel with flattened endothelium; *b*, blood-vessel with cubical and cylindrical endothelium.  $\times 250$ .

walls of which are more or less thickened and abnormally cellular, or else solid cords of cells (Fig. 260, *b*), which are either collapsed, thick-walled vessels, or possess no lumen whatever.

In very rare cases it happens that in angiomata, which from the calibre of the vessels bear the character of cavernous angiomata, there occurs a hypertrophy of the vessel-walls; and this hypertrophy is due to the fact that the flat endothelial cells become changed into cubical and cylindrical cells (Fig. 262, *b*). Such a tumor may be classed as an *angioma cavernosum hypertrophicum*, or as a *blood-vessel-endothelioma*, or *hæmangioitic endothelioma*; the last term being in particular applicable when, as a result of the marked proliferation and multiplication of the endothelium, there are produced nests of large cells which fill up the blood-vessels (compare Endothelioma, §§ 115 and 116).

A **cirroid aneurism**, or **angioma arteriale racemosum**, or **angioma arteriale plexiforme** (Fig. 263), is a condition in which the arteries of an entire vascular area are dilated, tortuous, and thickened, so that there is



formed a convolution of enlarged and thickened arteries. To the palpat-  
ing finger they feel like a bunch of earth-worms. Many of these angio-  
mata, which occur particularly upon the head, and which may cause

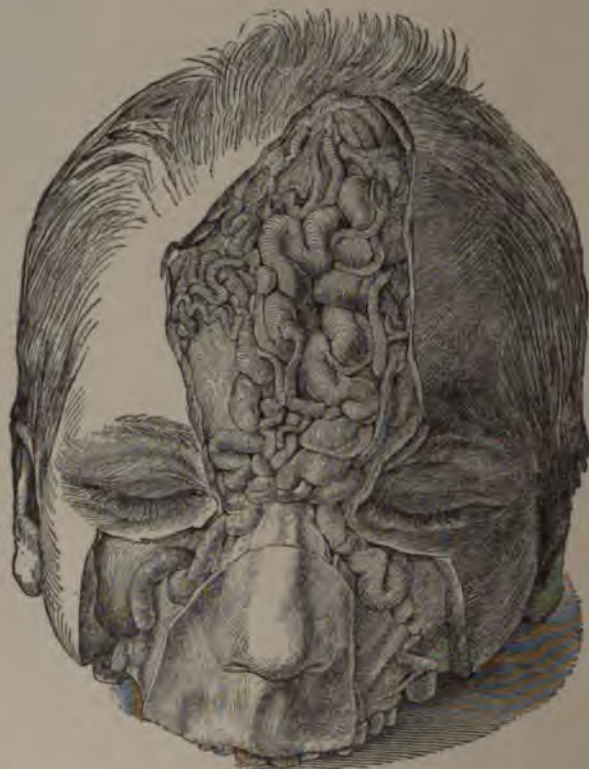


FIG. 263.—Angioma arteriale plexiforme arteriæ angularis et frontalis dext. et sin.

erosion of the cranial bones, arise from congenital anlage; others appear to be acquired, and develop after a traumatism, but it is possible that special conditions may have existed before the trauma.

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 See also § 116.

§ 109. **Angioma lymphaticum** or **lymphangioma** is a tumor composed of a tissue the greater part of which is made up of *dilated lymph-vessels*. The following different forms may be distinguished: *lymphangioma simplex* or *teleangiectasia lymphatica* (Fig. 264); *lymphangioma cavernosum* (Fig. 265); *lymphangioma cystoides*; and *lymphangioma hypertrophicum*. The cavities of these tumors usually contain a clear, light-colored lymph, but more rarely it is milky and contains mononuclear and polynuclear leucocytes, and usually also eosinophile cells. The walls consist of connective-tissue trabeculæ of varying thickness and containing more or less involuntary muscle; the spaces are lined with endothelium.

In the **lymphangioma simplex** (Fig. 264) the lymph-vessels of a more or less extensive area are dilated and their walls for the greater part are thickened. In the **cavernous lymphangiomata** the number of

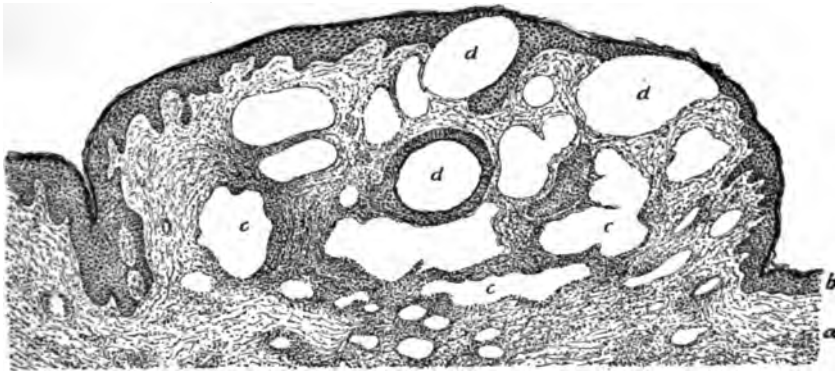


FIG. 264.—Weeping subepithelial lymphangioma of the skin (alcohol, carmine). a, Corium; b, epithellum; c, d, lymph-spaces.  $\times 14$ .

lymph-vessels is still greater, their spaces are larger, and the intervening tissue is less abundant, so that, even to the naked eye, the tissue presents a spongy appearance. The **cystoid lymphangiomata** contain cysts varying in size from that of a pea to a walnut. The tissue between the dilated lymph-vessels consists, according to the location of the tumor, either of connective tissue (Fig. 264), fat tissue (Fig. 265, c), muscle, or some other tissue. At times nodes of lymphadenoid tissue may be enclosed (e), and may present evidences of active proliferation.

Lymphangiomata are sometimes congenital; at other times they make their first appearance at a later period of life.

The congenital forms occur particularly as different varieties of ectasia of lymph-vessels, and are found chiefly in the tongue (*macroglossia*), palatal arch, lips (*macrocheilia*), skin (*nævus lymphaticus*), subcutaneous tissue, in the neck (*hygroma colli congenitum*), vulva, etc. The *lymphangiomata of the skin* spread over more or less extensive areas of the skin, and form either smooth or irregular elevations of the same. If the blood-vessels are numerous the growth may have a red color. The rupture of dilated lymph-vessels lying immediately beneath the epithelium (Fig. 264, *d*) may give rise to a moist condition of the surface and

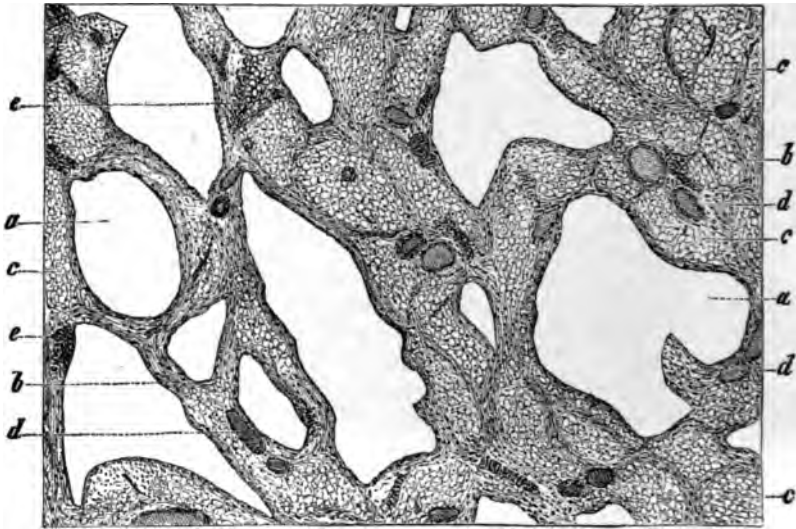


FIG. 265.—Lymphangioma cavernosum subcutaneum (alcohol, alum-carmin). *a*, Ectatic lymph-vessels; *b*, connective tissue; *c*, adipose tissue; *d*, large blood-vessels; *e*, cellular areas.  $\times 250$ .

eventually to a lymphorrhœa. The extension of the cavernous development of the lymph-vessels over large areas of the skin and subcutaneous tissue may give rise to *elephantiasis-like disfigurements* of the part affected. Not infrequently the intervening connective tissue also takes part in the hypertrophic growth, or there develops a fibrous elephantiasis in connection with lymphangiectasia.

In rare cases chyle-containing growths (*chylangiomata*) are found in the intestinal wall or mesentery. *Cystic lymphangiomata* are also found rarely in the *peritoneum*.

The pathological formations which may be classed as **hypertrophic lymphangiomata** represent peculiar changes of the skin, which are either congenital or develop in early youth. They are commonly known as pigmented moles, lentigines, freckles, and fleshy warts.

The *pigmented moles*, or *nævi pigmentosi*, or *melanomata*, form larger or smaller smooth areas which are not elevated above the general surface of the skin (*nævus spilus*), or prominent warty growths (*nævus prominens*, *nævus verrucosus*). When covered with hair, as is frequently the case, they are called *hairy moles* (*nævus pilosus*). In color they are usually light brown or dark brown, or even black (Fig. 266); and are usually



covered by epidermis of normal thickness, more rarely by hypertrophic epithelium. They are usually small, but may be as large as the palm of the hand, or under certain conditions may cover a large part of the body surface.

*Lentigines* appear at any time after birth, and upon any part of the body surface; and when once formed they remain for life. They form sharply circumscribed yellow to brownish-black spots closely resembling the little pigmented naevi; and vary in size from that of a pinhead to that of a lentil.

*Freckles* or *ephelides* are small, irregularly outlined, serrated, pale-brown spots, which are not elevated above the surface of the skin. They occur in young individuals, particularly on the face, hands, and arms, rarely on other portions of the body; and may either remain permanently or disappear after a longer or shorter time. The pigmentation is favored by exposure to sunlight.

*Fleshy moles* (*verruca carnea*) are non-pigmented, circumscribed, smooth (Fig. 267) or slightly irregular, or more rough and papillary (Fig. 269) prominences of the skin, over which the epidermis is at times normal, at other times somewhat hypertrophic (Fig. 269, a).

In all of the pathological formations just described the connective-tissue framework encloses *collections of cells*, either in round or cord-like masses (Figs. 267, 268, 269, d, d<sub>1</sub>), which lie partly in the papillae and partly in the corium; and are the more abundant the more the growth pro-



FIG. 266. — Large hairy and pigmented naevus of back, buttocks, and thighs, with scattered smaller pigmented spots over the remaining portions of the body. (After Röhring.) (Reduced from original.)



FIG. 267. — Lymphangioma hypertrophicum. Section through a small, soft, smooth wart (formalin, hæmatoxylin, eosin).  $\times 40$ .

# TUMORS.



FIG. 268.—Lymphangioma hypertrophicum. Rounded summit of a large, soft, smooth wart (formalin, haematoxylin, eosin). Sharply outlined cell-nest in corium.  $\times 250$ .

jects above the surface of the skin. In the pigmented forms the cell of the cell-nests may also contain the pigment (chiefly in the form of brown or yellow granules, but in part diffused throughout the substance

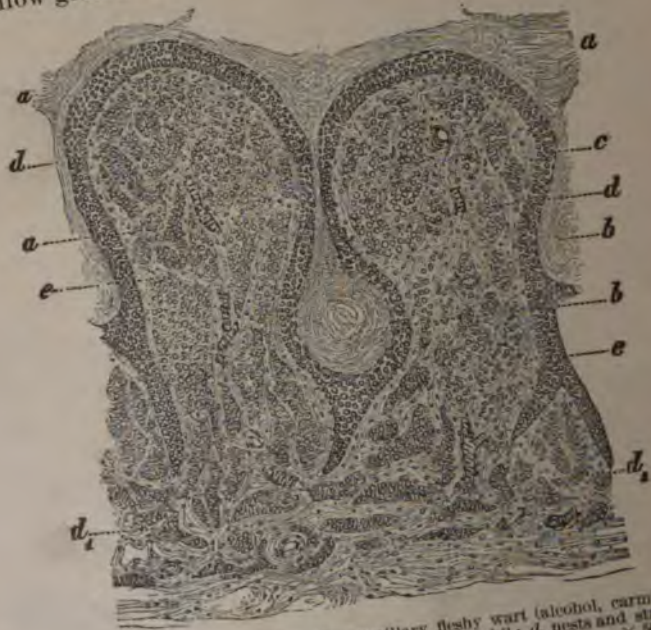


FIG. 269.—Section through two papillae of a papillary fleshy wart (alcohol, carmalum). horny layer of the epidermis; b, epithelial pearls; c, rete Malpighii; d, nests and strands of cells in the reticular layer; e, connective tissue.  $\times 50$ .

of the cells); though often the pigment lies chiefly within the connective tissue cells of the fibrous portions of the growth.

The cells of the cell-nests are relatively large (Fig. 268), possess an abundant protoplasm, and a bright, bladder-like nucleus. Their position and appearance justify the assumption that they represent the products of the proliferation of the endothelial cells of the lymph-vessels. In rarer cases similar formations arise from the blood-vessels (hæmangioma hypertrophicum). Accordingly, it would seem proper to class these growths with the endotheliomata or lymphangiosarcomata, but their limited growth makes their classification as lymphangiomata more appropriate (see § 115). The cell-nests of the hypertrophic lymphangioma may in part spread out more diffusely through the tissues (as is the case with the hypertrophic hæmangioma), so that the peculiar structure of the growth may be lost. In rare cases there may develop a combination of hypertrophic lymphangioma and lipoma.

*Unna, Kromayer, Delbanco, and Marchand* hold the view that the cell-nests of the cellular nævi are of epithelial origin, and represent misplaced portions of the surface epithelium; and *Kromayer* goes so far as to assume a metaplasia of epithelium into connective tissue. Preparations showing the first stages of the development of nævi are not accessible to me; but a thorough study of nævi and fleshy warts of a later stage does not show any connection between the cell-nests and the epithelium; and consequently I hold the opinion—notwithstanding the investigations of the above-named authors—that the view given above in the text, in regard to these nævi and fleshy warts, harmonizes most perfectly with their anatomical nature and clinical behavior, both in their fully developed condition as well as when they undergo a transformation into malignant sarcomata. That in individual cases the cell-nests lie close to the epithelium is no proof of a genetic relationship, since the ordinary lymphangiomata also lie close to the epithelium (Fig. 264, d).

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(g) *Myoma*.

§ 110. A **myoma** is a tumor consisting essentially of *newly formed muscle-fibres*. According to the nature of the muscular elements, myomata are divided into *leiomyomata* formed of *unstripped muscle*, and *rhabdomyomata* composed of *striped muscle*.

The **leiomyoma**, or *myoma levicellulare*, occurs most frequently in the uterus, more rarely in the tubes, uterine ligaments, labia majora, mus-



FIG. 270.—Myoma of the uterus (Müller's fluid, hæmatoxylin, eosin).  $\times 300$ .

cularis of the gastro-intestinal tract and urinary passages; and may form spherical, nodular tumors of varying size. In rare cases it is found also in the skin and subcutaneous tissues, forming in this location small

nodules occasionally reaching the size of a pigeon's egg. Leiomyomata occur as either single or multiple tumors; and may appear during childhood, or even develop under certain conditions during intrauterine life (Mare).

In muscular organs the new-growth proceeds from the muscularis, and forms during its development bundles of muscle-fibres (Fig. 270) which are interwoven in different directions, and consequently present

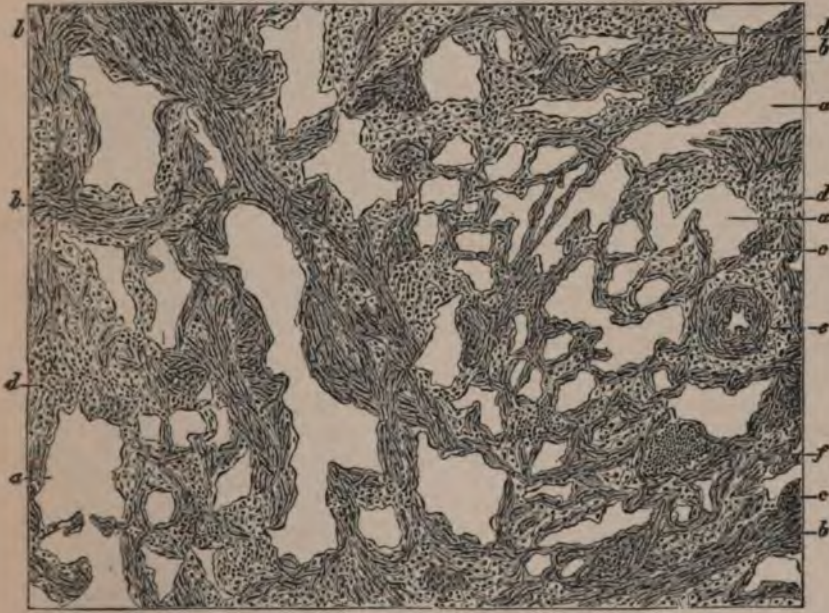


FIG. 271.—Angiomyoma subcutaneum dorsl (alcohol, hæmatoxylin, eosin). *a*, Cavernous blood-vessels; *b*, strands of muscle cut longitudinally; *c*, same cut transversely; *d*, connective tissue; *e*, artery with hypertrophic muscularis; *f*, groups of lymphoid cells.  $\times 46$ .

in sections a variety of pictures according to the directions in which the bundles are cut. Myomata of the uterus may contain included uterine glands. Those developing in the dorsal wall of the body of the uterus and near the angles of the tubes, or in the inguinal region, may contain a varying number of gland-tubules which arise from the Wolffian body (von Recklinghausen); such tumors may be designated *adenomyomata*. They are distinguished from the ordinary spherical myomata which are sharply circumscribed, by the fact that their boundaries are not sharply defined. Eventually some of the glands may become cystic as the result of the accumulation of secretions. According to Ricker, Pfannenstiel, and others, the ordinary uterine myomata as well as those of the vaginal vault may also contain epithelial tubes, which probably owe their origin to inclusions of portions of the duct of Müller. In the skin and subcutaneous tissue the new-formation of muscle-fibres proceeds in the first place from the muscularis of the vessels (Fig. 271), which thereby become thickened (*a*), and at the same time give rise to free strands of muscle-fibres (*b*). A pathological new-formation of blood-vessels may be associated with that of muscle (*a*), so that tumors arise which are designated *angiomyomata* (Fig. 271). According to observations by Jadassohn



and others, multiple myomata of the skin may take their origin either from the arrectores pilorum or from the muscle-cells of the sweat-glands.

A certain amount of connective tissue always takes part in the formation of a myoma, and often assumes such importance that the tumor may with propriety be called a **fibromyoma** or **myofibroma**. For example, the majority of the uterine myomata are fibromyomata. The fibrous connective-tissue portions of the tumor appear glistening white, the muscular portions more reddish-white or clear reddish-gray. The spindle-shaped muscle-fibres may be isolated by teasing a bit of the tumor or by maceration of the same for twenty-four hours in a twenty-per-cent nitric-acid solution or for twenty to thirty minutes in a thirty-four-per-cent solution of potassium hydroxide. In longitudinal sections the muscle-fibres are most easily recognized by their rod-shaped nuclei (Figs. 270, 271), as well as by the regular structure of the cells in bands or strands. In cross-section the muscle-cells appear as small flattened cells containing in their centres the transversely cut nuclei (Fig. 270).

The leiomyomata are benign tumors, but often reach a very large size, and sometimes undergo a sarcomatous proliferation. In fibromyomata of the uterus there not infrequently occur fatty degeneration and softening, which may lead to the disintegration of the growth or to the formation of cystic cavities. Calcification may also occur. Through degeneration and atrophy of the muscle-fibres a myofibroma may become transformed into a fibroma.

A **rhabdomyoma** (Zenker), or *myoma striocellulare*, is on the whole a rare tumor. Its most characteristic feature is the presence of striated muscle-fibres, which in part are fully developed and in part un-

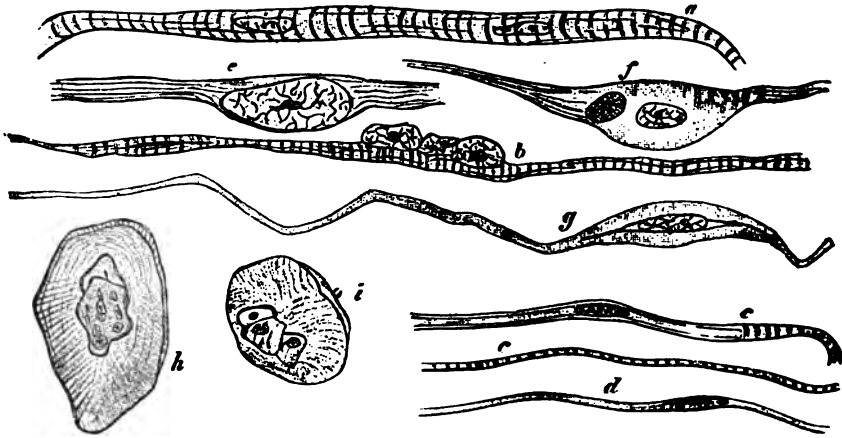


FIG. 272.—Cells from a rhabdomyoma. (After Ribbert and Wolfensberger.) *a, b, c, d.* Striated fibres of varying thickness; *d*, small nucleated fibre without striation; *e*, spindle-cell with longitudinal striation; *f*, spindle-cells with longitudinal and transverse striation; *g*, spindle-cells, without striation, with elongated processes; *h, i*, round cells with concentric and radial striation.

developed. When well developed the muscle-fibres form multinuclear bands of varying width, which present a cross-striation (Fig. 272, *a, b, c*), and in part also a longitudinal striation (*e, f*). The undeveloped forms consist of narrow bands without transverse striations (*d*); of spindle-cells with long-drawn-out thread-like processes without transverse striation (*g*) or with partial striation (*f*); or, further, of round cells of

different sizes, which present either a radial or a concentric fibrillation or striation (*h, i*). Besides these there are also cells which possess no especial characteristics, so that it is impossible to decide whether they are young undeveloped muscle-cells or connective-tissue cells. The bands as well as the spindles are usually arranged in interlacing bundles. It is usually not possible to demonstrate with certainty the presence of a sarcolemma on the surface of the fibres; but various delicate membranes have been described by different authors, which probably are to be regarded as representing portions of a sarcolemma.

Rhabdomyomata of the heart, in so far as they do not consist of a formation of delicate transversely striated muscle-fibres, are made up of a delicate network supported by connective-tissue bands, in the clear spaces of which network there lie spider-like cells, whose processes are partly free, and partly continuous with the reticulum. According to Seiffert, these cells are to be regarded as enlarged embryonal muscle-cells, which, in the event of an overproduction of the structureless protoplasmic portion, have formed no transversely striated covering.

Rhabdomyomata occur most frequently in the kidney or its pelvis, in the testicles, and uterus; more rarely in other regions, as, for example, in the vagina, bladder, muscles, heart, nerves, subcutaneous tissue, mediastinum, œsophagus, etc., and form nodular, or, in case they are situated on the surface of a mucous membrane, papillomatous and polypoid tumors, which vary greatly in size. They develop from striped muscle, possibly also from smooth muscle (uterus). In the kidneys and testicles they either form circumscribed nodules, or lead to a total destruction of the organ. The origin of the tumor in these cases is probably from misplaced anlage of muscle-tissue; and accordingly such growths are most frequently congenital. They may, however, develop first at an advanced age. Occasionally they enclose other tissues, for example, cartilage. Moreover, muscle-fibres of corresponding stages of development occur in the *complex tumors* of the testicles and kidneys (see Teratoma).

If a tumor contains only a few cells which can be definitely recognized as muscle-fibres, while the majority of the cells have no specific character, the tumor is ordinarily designated a *rhabdomyosarcoma*.

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(h) *Glioma and Neuroglioma Ganglionare.*

§ 111. A **glioma** is a tumor which develops from the *cells of the supporting tissue of the central nervous system* (neuroglia), and in its fully developed condition consists essentially of these cells. In the brain the gliomata form tumors, which for the most part are not sharply defined from the normal brain-sub-

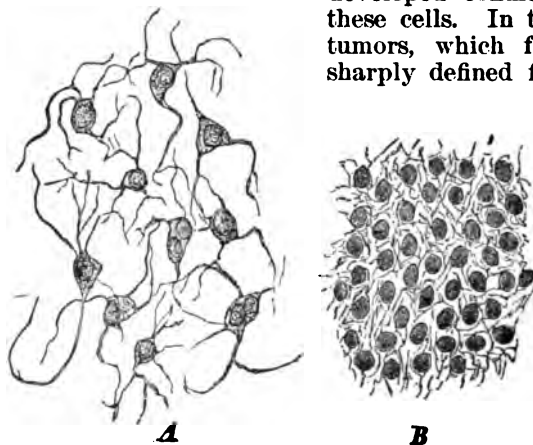


FIG. 273.—Glioma cerebri. A, Cells isolated by teasing and stained with carmine. B, Section from same glioma after hardening in Müller's fluid (Bismarck brown).  $\times 350$ .

stance, but pass into the latter by insensible gradations. At times they appear simply as local swellings of the brain, and only the difference in color and the disappearance of the normal tissue-contrasts between the different elements of the brain, give evidence to the eye that a tumor is present. In the spinal cord they arise most frequently in the neighborhood of the central canal, and may extend over a large portion of the cord.

Their appearance varies greatly; sometimes they are light-gray, somewhat translucent, and similar in color to that of the cortex, and moderately firm in consistence; at other times they are more grayish-white, denser, and firmer; and again they are not infrequently grayish-red or dark red in color. In the last case they are traversed by numerous

large vessels. Gliomata well supplied with blood often contain hæmorrhagic areas. Fatty degeneration, softening, and destruction of the tissue are also of common occurrence.

A section of a fully developed glioma shows under the microscope a network of extremely delicate glistening fibrillæ (Fig. 273, *B*), in which are imbedded numerous short oval nuclei. About the nuclei there is but a scanty amount of protoplasm, and this can be distinguished only with difficulty. When examined in the fresh state or after maceration in Müller's fluid it may be seen distinctly that these nuclei belong to cells (astrocytes) which are characterized by a great number of fine processes extending in all directions, and often branching (Fig. 273, *A*). By proper staining-methods the connection between some of the fibres may be demonstrated also in sections (Fig. 274).

The cells are very similar to normal glia-cells; but are not infrequently much larger, occasionally more plump, and some may possess two, three, or four nuclei.

Investigations as to the development of gliomata have proved that the glia-cells are the mother-cells of the tumor-cells. The ganglion-cells do not take any part in the proliferative process. Within the tumor there may be found cavities lined with ependyma-epithelium (Stroebe), and this may be regarded as evidence of their connection with some disturbance of development of the brain or spinal cord. The number of cells in a glioma varies greatly. At times the cells greatly predominate, at other times the fibrillæ. A simultaneous proliferation of the cells of the perivascular connective tissue leads to the formation of gliosarcomata.

The glioma usually occurs singly, and does not produce metastases. Traumatism may furnish the exciting cause for its development.

The term **glioma** is also applied to certain tumors of the **retina** occurring during childhood. These growths, a certain portion of which are of congenital origin, are evidently to be referred to some disturbance in the development of the retina. They form cellular, soft, white or reddish tumors, the greater part of which consists of small, round or irregular cells poor in protoplasm, resembling the cells of the stratum granulosum. In part they possess smaller or larger processes. These cells are found best preserved in the neighborhood of the blood-vessels, while in other portions of the tumor they often show retrograde changes. The tumor may also contain ganglion-cells, cylindrical cells, and peculiar rosette and ribbon-like cell-formations (Wintersteiner), these latter being regarded as aggregations of rods and cones. Wintersteiner has, therefore, designated the tumor a *neuroepithelioma*.

The glioma of the retina often shows areas of necrosis in its central portion. In its growth it may break into the retrobulbar space, or forward through the cornea and sclera; it recurs after operation, and gives rise to metastases.

A **neuroglioma ganglionare** (Fig. 275) is a tumor of the central nervous system, composed of hyperplastic glia-tissue, ganglion-cells, and

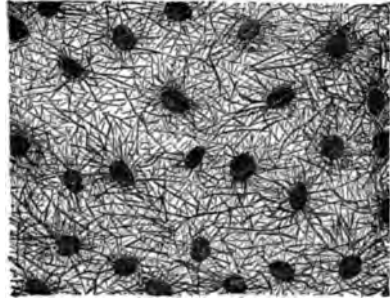


FIG. 274.—Section of a glioma of the cerebrum, with astrocytes (Müller's fluid, hæmatoxylin, Mallory's method.)  $\times 500$ .

nerve-fibres, and forms either poorly defined swellings of larger portions of the brain, or circumscribed, nodular enlargements of smaller portions. To the naked eye the structure of the brain may in general appear to be still preserved, though the difference between the cortical and medullary



FIG. 275.—Section from a nodular neurogloma ganglionare of the central convolution of the cerebrum (Müller's fluid, Weigert's stain). *A*, Portion of tissue rich in ganglion cells. *B*, Portion of tissue containing nerve-fibres. *C*, Jelly-like portion. *a*, Ganglion-cells arranged in groups; *b*, scattered ganglion-cells; *c*, ganglion-cells with two nuclei; *d*, nerve-fibres with medullary sheath; *e*, glia-cells; *f*, blood-vessel.  $\times 275$ .

substance is less distinct than normal, and the tissue throughout is white or grayish-white, or spotted gray and white, and at the same time more or less hardened.

The main portions of these masses consist of a more or less thick glia-tissue containing a certain number of nerve-fibres (*d*) and ganglion-cells (*a*, *b*, *c*), not only in the cortical region, but also in the white substance.

Probably all of these formations are to be regarded as the result of disturbances of the embryonal development of the brain—that is, as local malformations of the brain, which have undergone further development during extrauterine life.

As *neuroepithelioma gliomatosum microcysticum* there has been described by *Rosenthal* a tumor extending over ten segments of the spinal cord, which in its structure resembled a cystadenoma, and contained, in a gliomatous ground-tissue, gland-like formations and cysts lined with cylindrical cells of the character of ependyma-epithelium.

With reference to the origin of glia and ganglion cells from the ectoderm, various writers class the *gliomata in their different forms* with the epithelial tumors. Against this view it may be urged that the entire structure of these tumors favors their classification with the tumors derived from connective tissue and the supporting tissues. Glia-tissue is indeed a tissue which arises from a separation of ectodermal cells, but the middle germ-layer represents also a secondary formation from the inner germ-layer. In both tissues there occur such differentiations and transformations that the epithelial character is wholly lost. Even the ependymal epithelium, through its formation of basal processes, approaches in character the supporting cells. The especial position held by the nerve cells may be left out of consideration with a certain right, in so far as the classification of tumors is concerned, inasmuch as these cells only rarely and then only to a very limited extent occur as tumor-elements, or form tumor-like malformations.



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*(i) Neuroma and Neurofibroma.*

§ 112. The tumors designated **neuromata** occur most frequently on the ends of amputated nerves, where they form more or less prominent swellings, either circumscribed or blending into the surrounding tissue without any clearly defined demarcation. From the conditions of their origin they are known as *amputation-neuromata* (Fig. 276, *b*). The development of these neuromata is to be referred to the changes taking place after the nerves have been severed; during the development of connective tissue in the stump the ends of the axis-cylinders of the proximal portion of the affected nerve divide and grow longitudinally, so that the scar-tissue comes to be penetrated by nerves which at first have no sheaths, but are soon surrounded by medullary sheaths. The mass of nerves penetrating into the granulation tissue may be large or small, so that the connective tissue after a certain length of time may contain a very rich supply of nerves, which, radiating from the end of the old nerve, extend into the connective tissue in all directions (Fig. 276, *b*). The process is, therefore, an example of a useless *regenerative proliferation of a nerve-stump* exceeding the physiological needs.

As another form of so-called neuromata are classed those growths developing spontaneously, without external cause, along the course of nerves; and which consist essentially of *an increase in the connective tissue of the nerve*, usually of the outer, more rarely of the inner layer of the endoneurium.

At the point of tumor-growth the nerve-bundles become surrounded by a more or less thick layer of connective tissue, which is usually loose, more rarely dense (Fig. 277, *b, d*), or the bundles may be split apart into their individual fibres (*c*). Occasionally the perineurium takes part in the proliferation. In the case of large nerve-trunks the epineurium may be affected in association with the endoneurium and perineu-

rium of the individual bundles, although the process is most frequently confined to the endoneurium.

According to their structure these tumors are not true neuromata, but are **neurofibromata** or **fibromata of the nerves**. They are usually of *multiple* occurrence, and may extend throughout the entire peripheral nervous system, but are more often limited to a definite area of nerve-distribution. In very rare cases they occur in the nerve-roots and spinal cord. The nodules are sometimes situated along the course of the



FIG. 276. — Amputation-neuroma of the sciatic nerve (nine years after amputation of the nerve). Longitudinal section. *a*, Nerve; *b*, neuroma. Drawn from a preparation which had been hardened in Müller's fluid.  $\times 3$ .

nerve-trunks, sometimes on the finer branches, most frequently of the cutaneous nerves; and in the skin form more or less numerous, larger or smaller, tumor-nodules, for the greater part of soft consistence, to which the designation **multiple fibromata of the skin** is usually applied. The smallest nodules can be seen only with the microscope; the majority vary in size from that of a pea to that of a hazel-nut. Individual tumors may reach the size of a man's fist, the nerve-fibres being wholly lost sight of in the great mass of connective tissue. Atrophy of the fibres may be caused by the increasing connective tissue, the fibres finally vanishing completely. In addition to the formation of circumscribed nodules there may occur also in the affected area a *diffuse thickening of the nerves from hypertrophy of their connective tissue*. Moreover, with this condition there may be associated a hypertrophic proliferation of the connective tissue of the skin and subcutaneous tissue, leading to *elephantiasis-like thickenings of the skin*.

A third form of false neuroma is the **cirroid neuroma** (Bruns) or **plexiform neuroma** (Verneuil), a tumor formation which is characterized by the development in the domain of one or more nerve-branches of a convolution of tendril-like, twisted or interwoven, thickened and nodular nerve-strands (Fig. 278). When examined in detail this formation is also found to depend essentially upon a *fibromatosis of the nerves* (Fig. 277), the pro-

liferation of the endoneurium resulting partly in a diffuse and partly in a nodular thickening of the nerves. In addition, it may be found in such formations that the nerves of the affected area are *lengthened and thereby rendered tortuous*, while at the same time the *nerves are increased in number*, so that the number of the nerves of the skin and subcutaneous tissues is greater than under normal conditions. The condition must, therefore, be regarded as one of true neuroma, a *neuroma verum* associated with a *fibromatosis*. The nerves are for the greater part medullated (*neuroma myelinicum*). It is very difficult to determine to

what extent non-medullated nerves are present in such formations, but nevertheless cases have been reported in which the nerve-fibres were for the greater part non-medullated (neuroma amyelinicum). Cirroid neu-



FIG. 277.—Nerves from an elephantiasis-like cirroid neuroma of the cheek and lower jaw (Flemming's solution, safranin). *a, b*, Nerves, the outer layers of whose endoneurium have undergone morbid proliferation; the nerve-fibres lie in the axial portion; *c*, nerve with markedly proliferated endoneurium and separated nerve-fibres; *d*, thickened nerve with a small strand of nerve-fibres at the left end; *e*, loose connective tissue, rich in nuclei and containing fat, lying between the nerves.  $\times 7$ .

romata occur on the head, trunk, and extremities, and give rise usually to *elephantiasis-like disfigurements* of the affected areas.

**True neuromata** consisting of nerve-fibres and ganglion-cells (*neuroma gangliocellulare verum*) are rare tumors; but from the observations of Weichselbaum, Beneke, Busse, Knauss, Schmidt and others, the occurrence of such growths cannot be doubted. They form tumors varying in size from that of a millet-seed to that of an apple, and develop particularly in the sympathetic system. In a case described by Knauss there were present multiple, nodular neuromata of the skin containing nerve-cells, and it is probable that these growths had their origin in sympathetic nerves containing gan-



FIG. 278.—Cirroid neuroma of the sacral region. (After a drawing by P. Bruns). The nodular, twisted, and interwoven nerves are in part free (*a*), and in part (*b*) covered by connective tissue. Natural size.

glion-cells. These tumors consist of connective tissue, non-medullated and medullated nerve-fibres, and ganglion-cells which resemble those of the sympathetic ganglia.

Both the *neurofibroma* and the *true neuroma* are, as regards their origin, to be referred to a *congenital anlage*. They form no metastases, but cases occur in which neurofibromata take on a sarcomatous character and thereby become malignant.

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#### (*k*) *Sarcoma.*

§ 113. A **sarcoma** is a connective-tissue tumor whose elements, either because of their number or often because of their size, predominate over the intercellular substance. Sarcomata are closely related to the undeveloped connective tissues, so that sarcomatous tissue may be compared with *embryonal tissue*.

Sarcomata develop either in previously normal tissue belonging to the connective-tissue group—as, for example, in the skin, subcutaneous tissue, intermuscular connective tissue, periosteum, spinal cord, meninges, connective tissue of the glands, etc.—or in some preëxisting connective-tissue tumor, as a fibroma, myoma, chondroma, hypertrophic lymphangioma, etc. The transformation of the parent tissue into tumor

tissue takes place through the growth and multiplication of the existing cells. The division of the cells takes place chiefly by mitosis, and mitoses are the more abundant the more rapid the growth of the tumor. In addition to typical mitoses there are frequently observed atypical forms, also nuclear fragmentation, and more rarely segmentation.

In their fully developed state sarcomata form more or less sharply circumscribed growths. They may appear in any portion of the body where connective tissue is present; but are found in certain tissues more frequently than in others. Thus, for example, they are found much oftener in the skin, fascia, intermuscular connective tissue, bone-marrow, periosteum, brain, and ovaries, than in the liver, intestines, uterus, and lungs.

The development and form of the cells vary greatly in different sarcomata. The intercellular substance is sometimes very scanty, soft, and delicate; at other times more abundant and in character resembling the ground-substance of the mature normal connective-tissue substances.

The amount of the intercellular substance has a marked influence upon the consistence and color of the tumor. The **medullary forms** are soft and very cellular, and poor in intercellular substance; on section they present a marrow-like white or grayish-white surface. The hard, dense forms, on the other hand, are poor in cells and rich in fibrous intercellular substance; they pass by insensible gradations into fibromata. Transition-forms are known as **fibrosarcomata**. The cut surface of a sarcoma presents a nearly uniform appearance, in case retrograde changes or differences in the blood-content do not cause alterations of the same; it is usually uniformly smooth, in the medullary forms milk-white, in the firmer varieties clear grayish-white, somewhat translucent, or more of a clear grayish-red or grayish-brown color. The hard forms are glistening white or yellowish-white.

The development of the blood-vessels varies greatly; sometimes the vessels are very numerous, large, and ectatic (*teleangiectatic sarcoma*). Usually the vessels have walls easily distinguishable from the tumor tissue; but the tumor-cells may also constitute the outer cells of the vessel-wall; and in such a case the cells of the vessel-walls also take part in the growth of the tumor. Lymph vessels have not been demonstrated in sarcomata.

Retrograde changes—such as fatty degeneration, mucous degeneration, liquefaction, caseation, necrosis, hæmorrhage, gangrene, ulceration, etc.—are of frequent occurrence in sarcomata.

The sarcomatous tumors may be divided into three classes. The first of these includes the *simple sarcomata*, or sarcomata in the narrower sense—that is, tumors of the type of embryonal connective tissue, showing a more or less uniform distribution of the cells without the formation of distinct groups of cells. The second class includes those sarcomata which show a *special arrangement and grouping of the individual elements*, so that tumor-formations arise which are very similar to the epithelial tumors. The third class is characterized by the appearance of *secondary changes in the cells, in the intercellular substance, and in the blood-vessels*, these changes giving to the tumors concerned a characteristic appearance.

The *etiology of sarcoma* is not a simple one. It occurs more frequently in youth than in old age. Some sarcomata develop even in embryonic life, and the origin of such may be referred to some local malformation. Occasionally trauma appears to be an exciting cause. A parasitic origin has not been demonstrated (see Etiology of Carcinoma). Usually only



one primary tumor is formed, but multiple primary sarcomata sometimes occur, particularly in the skin and bone-marrow. The softer tumors give rise to metastases.

§ 114. The **simple sarcomata** include both soft medullary forms and those of a firmer consistence, which pass by insensible degrees of transition into the *fibrosarcomata* and *fibromata*. According to the character of the cells, several forms may be distinguished.

The **small round-celled sarcomata** are very soft, quickly growing tumors, which develop particularly in the connective tissue of the motor apparatus and supporting framework, and also in the skin, testicles, ovaries, and lymph-glands. On section they appear milky-white, and occasionally present caseous or softened areas. When scraped the cut surface yields a milky fluid. Their structure is very simple; the tumors consist almost wholly of round cells and blood-vessels (Fig. 279, *c*). The cells are small and frail; they possess very little protoplasm, and have spherical or slightly oval, rather large, bladder-shaped nuclei (*c*), which appear to be more highly developed than the nuclei of lymphoid cells.

Between the cells lies a very scanty amount of fibrogranular intercellular substance. The vessels traverse the masses of cells in the form of thin-walled canals. If such a tumor growing in muscle be examined at its periphery it appears as an aggregation of round cells (Fig. 279, *b, c*) in the intermuscular connective tissue. Not infrequently lymphoid cells lie near the tumor-cells, the nuclei of the former (*d*) staining more intensely than those of the tumor-cells.

A second form of round-cell sarcoma is designated **lymphosarcoma** or **sarcoma lymphadenoides**; it imitates to a certain extent the struc-

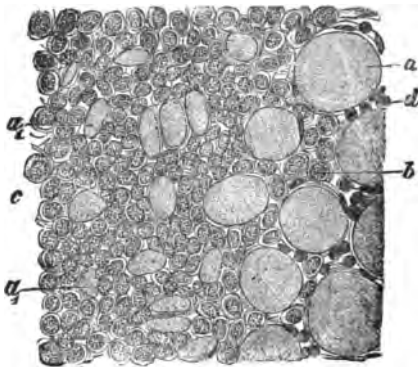


FIG. 279.

FIG. 279. Section through the edge of a sarcoma of the intermuscular connective tissue of the cervical muscles (alcohol, carmine). *a*, Transverse section of normal muscle; *a*<sub>1</sub>, transverse section of an atrophic muscle-fibre; *b*, round cells of the sarcoma, between the muscle-fibres; *c*, fully developed tumor; *d*, leucocytes.  $\times 300$ .

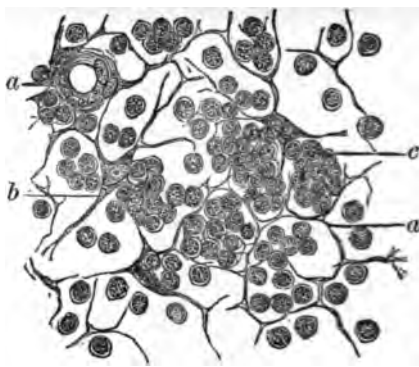


FIG. 280.

FIG. 280. - Section from a lymphosarcoma of the nasal mucous membrane (alcohol, carmine). *a*, Reticulum; *b*, cells of the reticulum; *c*, round cells; *α* (at the upper left), blood-vessel with proliferating cells.  $\times 300$ .

ture of a lymph-gland in that the stroma for the greater part of the round cells consists of a vascular reticulum (Fig. 280, *a*), which in part at least is composed of branching and anastomosing cells (*b*), as may be demonstrated by shaking a small section of the tumor in a test-tube.

According to the amount of the reticulum which they possess, the *lymphosarcomata* may be divided into the *soft* and *hard* forms. In the denser varieties the reticular framework may take on more and more the appearance of ordinary fibrous connective tissue.

Lymphosarcomata arise most frequently in the lymph-glands and the adenoid tissue of the mucous membranes, in the spleen and medias-



FIG. 281.

FIG. 281.—Section from a fungoid large round-celled sarcoma of the skin of the leg (carmine preparation).  $\times 400$ .



FIG. 282.

FIG. 282.—Section from a sarcoma of the mamma with cells of different shapes (alcohol, Bismarck-brown). *a*, Connective tissue; *b*, sarcoma tissue; *c*, small cells; *d*, cells with hypertrophic nuclei; *e*, multinuclear cells.  $\times 300$ .

tinum, but are found also in other places. The tumor-proliferation involves successively a more or less considerable portion of the lymph-adenoid tissues named.

**Large round-celled sarcomata**, the cells of which are much larger than those of the forms just described, appear in the same places as do the small round-celled variety, and closely resemble the latter. The cells possess an abundant protoplasm and large, bladder-like, oval nuclei (Fig. 281). Many of the cells have two nuclei, some more than two. Between the round cells there lies a reticulated intercellular substance (Fig. 281), as well as spindle-shaped and branched cells, which together form an alveolar network in whose meshes lie the large round epithelial-like cells. Such tumors are designated *large round-celled alveolar sarcomata* (Billroth).

In other forms of large round-celled sarcomata the tumor-cells are very unequal in size (Fig. 282), and at the same time there are mingled with the round cells elongated or irregularly shaped cells, so that the tumor may be called also a **sarcoma with polymorphous cells**. The nuclei likewise vary greatly in size (Fig. 282), and in individual cells (*e*) may be present in large numbers (multinuclear giant-cells).

The large round-celled sarcomata and the polymorphous-celled variety are on the whole less malignant than the small-celled, but they also give rise to metastases.

**Spindle-celled sarcomata** belong to the most commonly occurring tumors. As a rule, they are much firmer than the round-celled forms, but soft medullary forms also occur. On section they present ordinarily a grayish-white or yellowish-white, rather translucent surface, which may be more or less reddened according to its vascularity. Medullary tumors whose cells have undergone fatty degeneration may possess a

pure white color. In general, these sarcomata are more benign than the round-celled varieties, but their character in this respect varies according to their location and their richness in cells.

According to the size of the cells there may be distinguished **large spindled-celled** and **small spindle-celled sarcomata**. Through the teasing of small pieces of the tumor the cells may in part be isolated, and in this way very long spindles may be obtained (Fig. 283). The cells lie side by side with their flat sides approximated, and are grouped in bundles, which, in sections, are cut partly longitudinally, partly transversely, and partly obliquely—evidence that they are interwoven in different directions.

The arrangement of the spindles in bundles is often very striking; in other cases it is wanting; and the spindles for considerable distances run in the same direction. Sometimes the direction of the spindles is determined by the direction of the blood-vessels—that is, the individual bundles form sheaths about their respective blood-vessels.

Between the spindles there is often but a very scanty intercellular substance, or it may not be possible to demonstrate in sections the presence of such. In other cases it may be more abundant, and show a fibrillar character. The cells in such cases have less protoplasm, so that often it is scarcely possible to demonstrate any protoplasm around the nucleus, and the processes at the poles of the cells seem to spring directly from the nucleus (nuclear fibres). Such varieties are dense and hard. They

represent the connecting-link between sarcomata and fibromata, and are designated **fibrosarcomata**.

**Sarcomata with polymorphous**

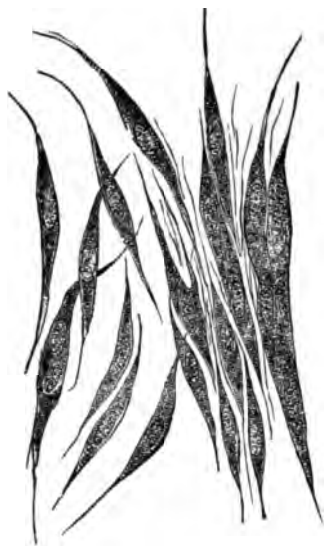


FIG. 283.

FIG. 283. Spindle-cells from a large spindle-celled sarcoma of the cheek (teased preparation).  $\times 400$ .



FIG. 284.

FIG. 284. Cells from a myelogenous giant-celled sarcoma of the tibia. (Hæmatoxylin.)  $\times 400$ .

cells are found also among the spindle-celled forms; and contain spindle-shaped, pyramidal, prismatic, stellate, and very irregular cell-forms (Fig. 284).

Both in polymorphous and spindle-celled sarcomata there may be found more or less numerous giant cells (Figs. 282, 284, and 285), so that the designation **giant-celled sarcoma** may be applied to these tumors.



They arise particularly from the bones, but they may occur also in other places.

If a sarcoma develops in preëxisting new-growths there may be formed mixed tumors, which are known as **myxosarcoma** (Fig. 243), **chondro-**



Fig. 285.—Giant-celled sarcoma of the upper jaw (Müller's fluid, hæmatoxylin).  $\times 100$ .

**sarcoma** (Fig. 248), **myosarcoma**, etc. The formation of bone within a sarcoma leads to the formation of an **osteosarcoma**.

The *lymphosarcoma of the lymph-glands and lymphadenoid apparatus of the spleen and the mucous membrane of the gastrointestinal tract* gives rise to a peculiar disease of these organs, which is characterized by a progressive increase of the lymphadenoid tissue, leading to the formation of extensive nodules. Under these circumstances the characteristic structure of the lymphadenoid apparatus is lost, and the newly-formed tissue shows a marked departure from the structure of typical lymphadenoid tissue—namely, a fibrous thickening of the reticulum or the formation of giant-cells. Since similar growths occur also in other organs, such as the liver, the disease cannot be looked upon as a pure hypertrophy of lymphadenoid tissue, but is closely related to tumor-formation. It is also possible that it is an infectious disease. Likewise the condition known as *sarcomatosis cutis*, which is characterized by the formation of numerous round-celled nodules in the skin, shows peculiarities which suggest an infection.

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 See also §§ 115-117.

§ 115. **Sarcomata which present an organoid structure** appear in those forms known as **alveolar and tubular sarcomata**. These are connective-tissue tumors in which the cellular elements, especially the larger cells, are arranged in groups, so that it is possible to distinguish a *vascular connective-tissue stroma* and *strands or nests of cells*. According to their genesis, these growths may be divided into two types: *lymphangiosarcoma* and *hæmangiosarcoma*. There are, however, also alveolar sarcomata which possess stroma and cell-nests, but which, in so far as their development is concerned, cannot be included with the above-named types.

The **lymphangiosarcomata** are tumors which arise from a *proliferation of the endothelium of the lymph-vessels and lymph-spaces*. They may accordingly be designated as **lymphangioendotheliomata** or as *endotheliomata in the narrower sense*. They may develop either in previously normal tissue, or in preëxisting tumor-like formations, such as the hypertrophic lymphangioma in particular (pigmented moles and warts, see § 109), and also from myxochondromata. The first occur particularly in the meninges of the brain, and in the serous membranes of the great body-cavities; but may develop also in other organs; the second are found chiefly in the skin; while those arising from myxochondromata develop in the mixed tumors of the salivary glands, palate, and orbit.

The *endotheliomata of the inner meninges of the brain and spinal cord* occur partly as nodular growths and partly as flattened proliferations; they develop through the transformation of the flattened endothelium, which covers the connective-tissue network of the subarachnoideal tissue and pia, into cubical or even cylindrical cells (Fig. 286, *d, e*). In consequence, the new-growth at first presents the appearance of *gland-like formations*; in the event of a more active proliferation solid *nests of cells* are formed. Inasmuch as the pia is continued as a lymph-sheath around the cerebral vessels, there are formed around the latter strands of large epithelial-like cells (Fig. 286, *f, g, h*).

The *endothelioma of the dura mater* arises through a proliferation of the endothelium of the lymph-vessels, and leads, through the filling up of



the latter with large cells, to the formation of anastomosing cords of cells (Fig. 287, *c, d, e*), which in some places may still contain a lumen.

The *endotheliomata of the pleura or of the peritoneum* appear usually as flattened thickenings of the affected membrane, but scattered nodular elevations may occur throughout the areas of thickening. These growths



FIG. 288.—Section through an endothelioma of the pia mater and cerebral cortex, diffusely spread over the surface of the brain and spinal cord (Müller's fluid, hæmatoxylin). *a*, Superficial pia; *b*, pia in a sulcus; *c*, cortex; *d, e*, endothelial proliferations in the pia sheaths of the cortical vessels; *f, g, h*, endothelial proliferations in the pia sheaths of the cortical vessels; *i*, longitudinal section through a vein.  $\times 28$ .

are characterized by cords of large cells (Fig. 288, *b*), which, corresponding to the course of the lymph-vessels, traverse the hypertrophic and proliferating tissue of the serosa.

The *endothelioma of the mammary gland* is a rare tumor, which develops in the form of nodules, and takes its origin from a proliferation of the endothelium of the lymph-vessels and lymph-spaces (Fig. 289, *b, c*), and gives rise to the formation of large cords of cells (*c*) or of smaller cell-nests. The proliferating cells are characterized by a great variation in the size, character, and form of the nucleus and cell-body.

The *endothelioma of the skin*, which arises from the hypertrophic lymphangioma (warts and pigmented moles), resembles these in its general structure, and possesses also cell-nests of varying size (Fig. 268). Further, there also occur endotheliomata of the skin, which do not arise from warts, and may develop in great numbers (Spiegler, Mulert).

The *endothelial proliferations which arise in myxomata and myxochondromata* form cords of cells of different shapes (Fig. 243, *b*); but it should be noted that in these cases similar proliferations may also arise from the

# TUMORS.

vessels (Fig. 293, *c, d*), so that it is often impossible to decide as to the nature of the cell-strands. The alveolar, tubular, or plexiform structure of the endothelioma is marked only in the first stages of the tumor, and usually disappears

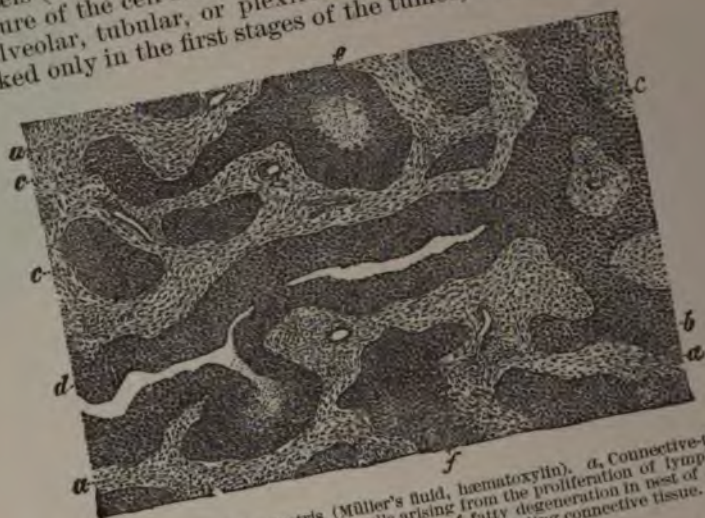


FIG. 287.—Endothelioma durum matrix (Müller's fluid, haematoxylin). *a*, Connective-tissue stroma; *b*, small-celled focus; *c*, groups and strands of cells arising from the proliferation of lymph-vessel endothelium; *d*, endothelial cell-strand with a lumen; *e*, area of fatty degeneration in nest of endothelial cells; *f*, strand of cells, passing gradually, on the right, into the surrounding connective tissue.  $\times 25$ .

in part with the advancing growth of the tumor. This is due, on the one hand, to the fact that the endothelial proliferation extends, without



FIG. 288.—Endothelioma of the pleura (alcohol, haematoxylin). *a*, Proliferated and thickened pleural connective tissue; *b*, cell-strands.  $\times 100$ .

sharp limits, into the neighboring connective tissue (Fig. 287, *f*); on the other hand, to the circumstance that the connective-tissue



take on a proliferative activity similar to that of the endothelium, so that there is formed a diffuse, cellular new growth of the character of

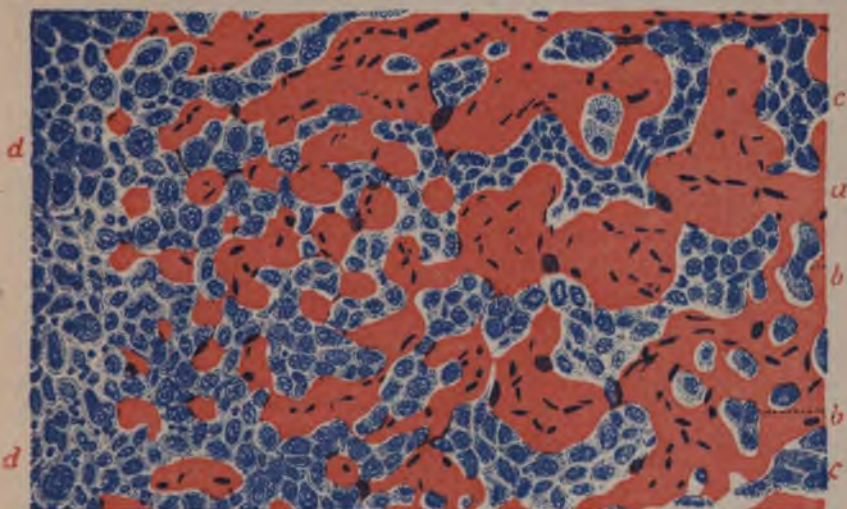


FIG. 289.—Endothelioma of the mammary gland (alcohol, haematoxylin, eosin). *a*, Connective tissue; *b*, enlarged cells in the connective-tissue spaces; *c*, strands of cells; *d*, diffuse cell-proliferation.  $\times 300$ .

an ordinary sarcoma (Fig. 289, *d*). Accordingly, the endotheliomata cannot be sharply distinguished from the sarcomata, and may become transformed into the latter.

The similarity in structure between endotheliomata and carcinomata raises the question whether it would not be expedient to class the former as *endothelial cancers*. The structure of these tumors would certainly justify such a classification, but I consider it better to avoid the use of this term. In the first place, the term endothelioma is in general use and is entirely appropriate, and the introduction of the term endothelial cancer would easily give rise to confusion; by the term cancer in general is understood an epithelial tumor, and it does not seem expedient to introduce two types of cancer—an epithelial and an endothelial.

I have classed as endotheliomata those tumors of the serous membranes which are characterized by the formation of cell-cords in the lymph channels, on the assumption that these cords of cells arise from the endothelium of the lymph-vessels and lymph-spaces. I must admit, however, that I do not consider this assumption as absolutely proved, in spite of the concurring definite statements of a number of authors (see *Glockner*). The possibility of their development from the epithelium of the serosa is not excluded (*Benda*), and if such an origin could be proved, the question would arise whether it would not be better to class these tumors with the carcinomata, since the corresponding tumors of the kidneys and ovaries, whose gland-cells arise from peritoneal epithelium, are classed with the epithelial tumors.

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 See also §§ 114 and 116.

§ 116. The **hæmangiosarcomata** represent a group of organoid sarcomata, in which the walls of the blood-vessels and their surrounding



FIG. 290.—Blood-vessel endothelioma of the kidney (formalin, hæmatoxylin, eosin). *a*, Vessels filled with blood; *b*, vessels filled with proliferated endothelial cells.  $\times 300$ .



tissue take an especial part in the building-up of the tumors, and constitute a characteristic feature of their structure.

One form of hæmangiosarcoma is the **blood-vessel-endothelioma** or **hæmangioendothelioma**, a tumor which arises, either from preëxisting

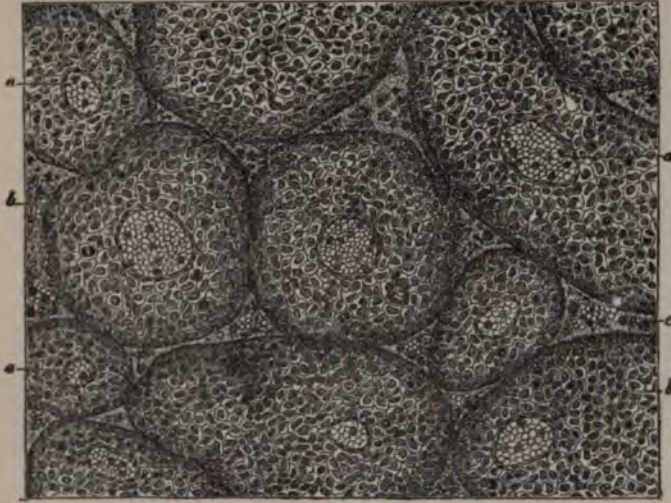


FIG. 291.—Section through a nodular angiosarcoma of the thyroid (Flemming's solution, safranin). *a*, Transversely cut vessels; *b*, perivascular cylinders of cells cut transversely and showing numerous mitoses; *c*, granular masses, with scattered cells, between the cell-cylinders.  $\times 73$ .

blood-vessels or those newly formed in hæmangiomata, through a more active development and proliferation of the endothelium giving rise to

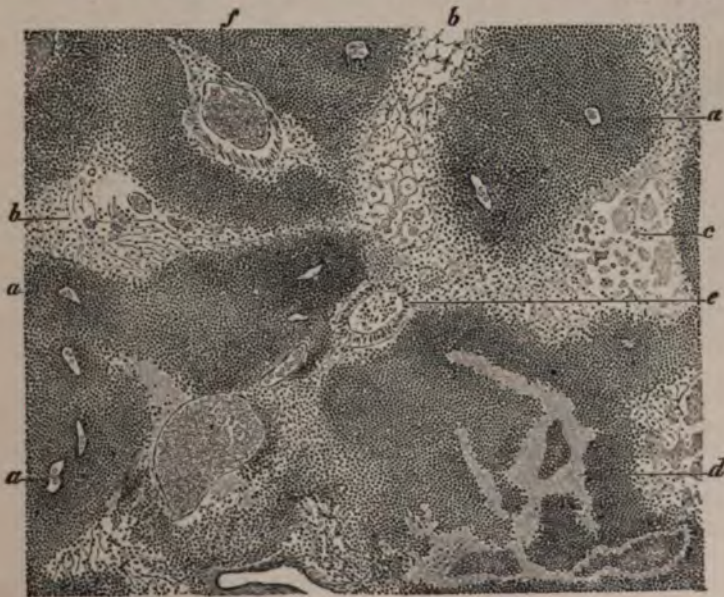


FIG. 292.—Angiosarcoma of the testis (Müller's fluid, hæmatoxylin, eosin). *a*, Perivascular masses of closely packed cells; *b*, areas poor in cells; *c*, hyaline lumps; *d*, hyaline masses containing blood; *e*, seminiferous tubules; *f*, large vein.  $\times 83$ .



blood-vessel spaces lined with cubical or cylindrical endothelium (Fig. 290), or to canals completely filled with such cells (*b*). According to the number of blood-containing vessels the tumor is either dark-red, pale, grayish-white or yellowish-white. The endothelial cells, according to the stage of development, may contain glycogen or fat or both.

A second form of hæmangiosarcoma, the **hæmangiosarcoma** in a narrow sense (occasionally also called *perithelioma*), arises through the proliferation of the tissue of the outer layers of the blood-vessel walls and their immediate surroundings, so that the vessel-lumina are surrounded by a more or less thick mantle of cells (Fig. 291, *b*).

In typical cases the tumor-tissue consists almost wholly of a confused tangle of blood-vessels (Fig. 291, *a*), whose walls are surrounded by a thick layer of cells, which often reach to the endothelium. The thick-walled tubes of cells sometimes run an isolated course, and at other times anastomose, so that variously formed twistings and interweavings result



FIG. 293.—Chondrosarcoma of the parotid with angiosarcoma (Müller's fluid, hæmatoxylin, eosin). *a*, Areas of cartilage; *b*, dense sarcoma tissue; *c*, blood-vessel; *d*, cell-strands arising from blood-vessels, and in part containing a hyaline substance.  $\times 80$ .

(*plexiform angiosarcoma*). The tissue lying between the cell-strands is the remains of the original tissue (Fig. 292, *b*), and may still contain characteristic tissue-formations, as, for example, glands (*e*).

Should a more active proliferation of the perivascular mantle of cells occur, and if these become confluent with each other (Fig. 292), the tumor passes over into an ordinary sarcoma. This change almost invariably occurs in the larger tumors of this kind.

Hæmangiosarcomata occur in the most varied organs: testicles, kidneys, salivary glands, bones, brain, mamma, thyroid, skin, carotid gland, ovaries, and liver. In the last-named organs they are rare. Both forms

may so occur that the tumor throughout bears the character of a hæmangiosarcoma; but it also happens that such proliferations of the vessels form only a single feature of other tumors (Figs. 293, *c, d*; 300, *d*); and though this feature indeed gives character to individual portions, it is, on the whole, overshadowed by other features of the growth—as, for example, a fibro-cellular tissue, cartilage (Fig. 293, *a, b*), or myxomatous tissue (Fig. 300, *a*).

Lymphangiosarcomata and hæmangiosarcomata cannot always be sharply differentiated from each other, and tumors occur to which both designations may be applied with propriety. The perivascular development of the endothelial proliferation within the brain in endothelioma of the pia (Fig. 286, *f, g, h*) would justify also the application of the term hæmangiosarcoma.

If in a lymphangiosarcoma of the skin there is such a rapid development of the cell-nests that the space between the vessels becomes wholly filled with cells, so that the framework of the tumor comes to consist only of blood-vessels (Fig. 294), it becomes an open question as to whether the tumor should be called a lymphangioendothelioma or a hæmangiosarcoma.

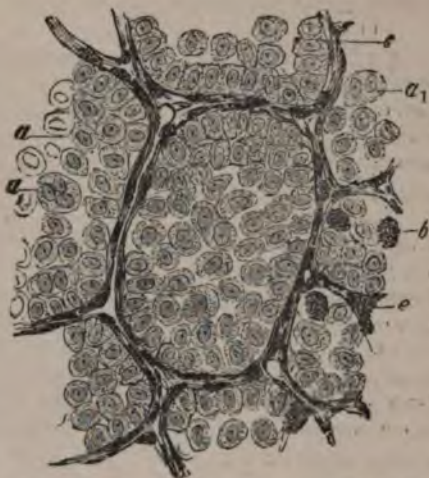


FIG. 294.—Alveolar melanotic sarcoma of the skin (alcohol, hæmatoxylin). *a*, Mononuclear, *a*<sub>1</sub>, multinuclear sarcoma cells of epithelial character; *b*, pigment-containing cells; *c*, stroma with blood-vessels and pigment.  $\times 300$ .

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See also §§ 115 and 117.

§ 117. **Sarcomata** which acquire a peculiar character through especial products of the cells or through changes in their ground-substance are to be found both among the simple and the organoid forms. The chief types belonging in this class are the melanosarcoma, chloroma, osteoid sarcoma, the petrifying sarcoma, psammoma, and the sarcomata containing hyaline formations.

**Melanosarcomata** occur in tissues which contain pigmented connective-tissue cells—*chromatophores*. They develop most frequently in the choroid of the eye and in the skin. In the latter case they arise chiefly from pigmented moles and lentigines. They belong to the malignant sarcomata, grow into the neighboring tissues, and give rise to metastases. The fully developed tumor is in whole or in part smoky gray to black or brownish-black, the color being due to the presence of round, angular, fusiform, and branched cells, which are filled with yellowish-brown pigment granules (Figs. 294, *b, e*; 295, *c*), or are stained a diffuse yellow. In the alveolar forms both the large cell-nests, as well as the smaller cells

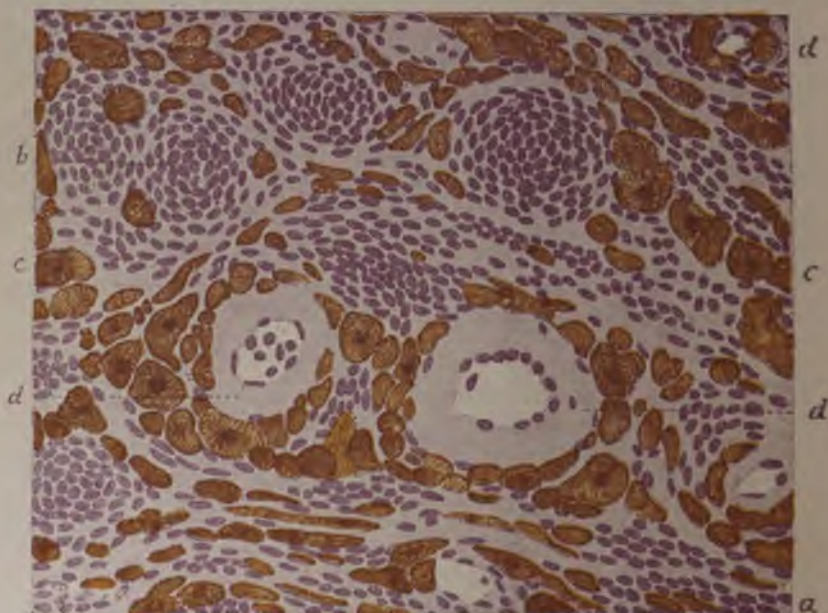


FIG. 295.—Melanotic sarcoma of the skin (alcohol, carmine, eosin). *a*, Sarcoma tissue rich in cells; *b*, cell-nests; *c*, pigment-cells; *d*, blood-vessels with hyaline walls.  $\times 300$ .

of the supporting framework, may contain pigment. It is often especially abundant in the neighborhood of the blood-vessels (Figs. 294, *e*; 295, *d*); but this pigment is not hæmosiderin (see § 70).

The metastases are likewise more or less pigmented (Fig. 296); and the smallest ones may consist essentially of pigmented cells (*c, d*). Cases occur in which numerous organs, the skin, muscles, pia, serous mem-

branes, and adipose tissue (Fig. 296) are spotted black through the formation of innumerable metastases.

**Chloromata** are tumors the cut surface of which presents a light-green color which on exposure to the air takes on a dirty appearance.

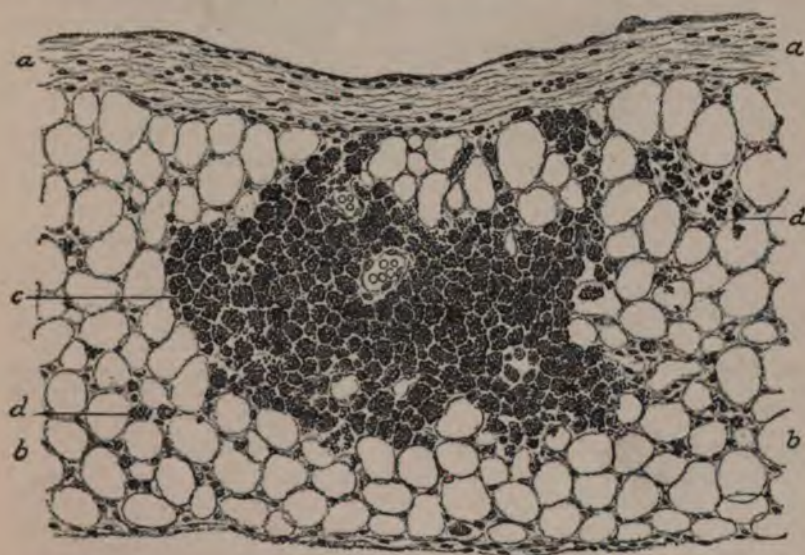


FIG. 296.—Metastasis of a melanotic sarcoma of the skin in the mesentery of the small intestine (formalin, alum-carmin). a, Peritoneum; b, fat tissue; c, sarcoma nodule; d, isolated chromatophores.  $\times 280$ .

They develop most frequently from the periosteum of the cranium; and consist of tissue made up of round cells and a reticular stroma. They may, therefore, be classed with the lymphosarcomata.

According to Chiari and Gruber, the green color is due to the pres-



FIG. 297.—Osteoid sarcoma of the ethmoid bone (Möller's fluid, hæmatoxylin, eosin). a, Sarcoma tissue; b, osteoid tissue; c, old bone-trabecula; d, vascular fibrous tissue.  $\times 45$ .



ence in the cells of small shining spherules which give the microchemical reactions of fat. In harmony with this view is the fact that the color

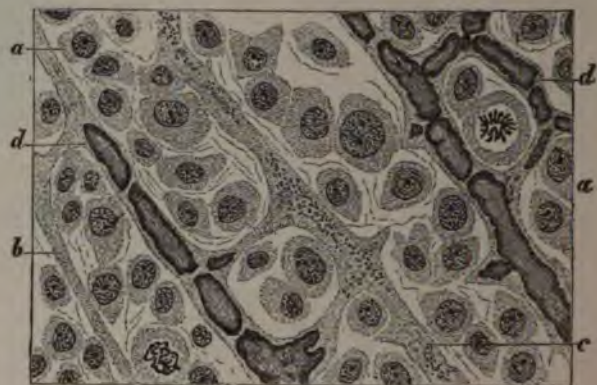


FIG. 298.—Petrifying large-celled sarcoma of the tibia (Müller's fluid, haematoxylin, eosin). *a*, Polymorphous tumor-cells; *b*, alveolar stroma; *c*, trabeculae of stroma containing small calcareous concretions; *d*, petrifying trabeculae of the stroma.  $\times 331$ .

disappears in alcohol. On the other hand, von Recklinghausen holds that the color is a property of the parenchyma.

**Osteoid sarcomata** develop in the bone-marrow and periosteum, and are characterized by a thickening of the ground-substance in certain areas, so that there are formed *trabeculae of osteoid tissue* (Fig. 297, *b*). Such tumors are closely related to the osteosarcomata but differ from them in the absence of deposits of lime-salts.

**Petrifying sarcomata** likewise occur most frequently in connection with the skeleton, and are characterized by the development between the

tumor-cells of trabeculae of a delicate ground-substance (Fig. 298, *c*), through the *calcification* (*d*) of which the tumor tissue becomes hardened, although no typical bone is formed.



FIG. 299.—Section from a psammoma of the dura mater (alcohol, picric acid, haematoxylin, eosin). *a*, Hyaline nucleated spherule enclosing calcareous concretion; *b*, calcareous concretion with hyaline non-nucleated border, inclosed in fibrous connective tissue; *c*, calcareous concretion surrounded by hyaline connective tissue; *d*, spicule of lime in the connective tissue; *e*, spicule with three concretions.  $\times 180$ .

**Psammomata** or *sand tumors* (acervulomata) are sarcomata or fibrosarcomata of the dura, inner meninges, or pineal gland, which contain *concretions of lime-salts* in greater or less abundance. Some of these concretions are similar in structure to the normal brain-sand, the basis of their formation being concentric layers of cells which have undergone hyaline degeneration (Fig. 299, *a*, *b*, *c*). Occasionally the chalky spherules lie inside of individual

cells and represent hyaline products of the cells which have later become calcified. Others are more of the nature of spicules (*d*), and arise through the deposit of lime-salts in connective tissue or blood-vessels which have undergone hyaline degeneration.



Psammomata usually form round nodules, and may be of multiple occurrence.

**Sarcomata with hyaline formations** (the myxosarcomata excepted) arise as follows: *Either the cells form hyaline products, or they themselves become converted into such, or the fully developed connective tissue and the blood-vessels undergo hyaline degeneration.* These changes may take place in simple sarcomata as well as in endotheliomata and hæmangiosarcomata; but occur much more frequently in the last-named tumor-forms (Figs. 288, *b*; 293, *d*; 300). The hyaline masses may form spherules, or club-like forms, or cords, or net-like or cactus-like figures. They push the cells apart, and often reduce them to narrow strands. Billroth has des-

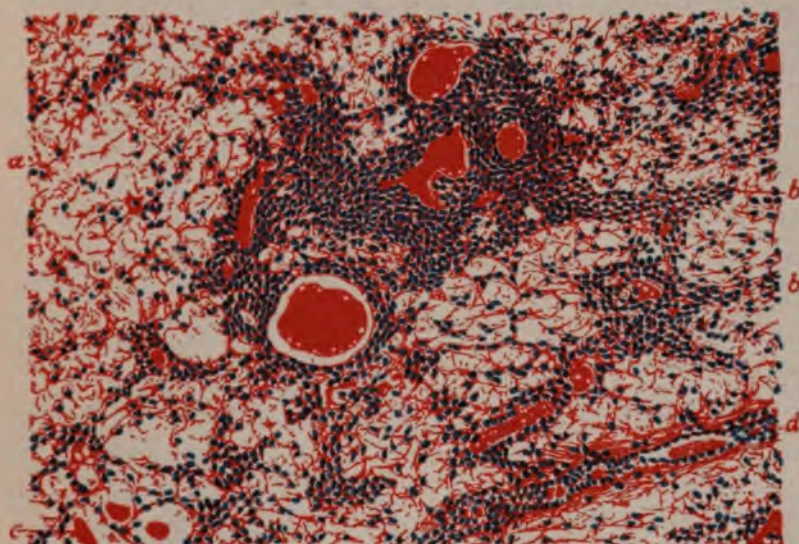


FIG. 300.—Myxo-angiosarcoma of the parotid, with hyaline formations (Müller's fluid, hæmatoxylin, eosin). *a*, Myxomatous tissue; *b*, cell-strands enclosing hyaline spherules; *c*, hyaline spherules in myxomatous tissue; *d*, blood-vessels with proliferating endothelium and hyaline spherules.  $\times 90$ .

ignated such tumors as *cylindromata*. In endotheliomata the hyaline degeneration may be associated with the formation of *laminated masses of flattened cells like the layers of an onion*, around a nucleus.

*Hyaline degeneration of the vessel-walls and of the connective-tissue bundles* results in a thickening of the same (Fig. 295, *d*), sometimes uniformly and sometimes irregularly distributed. *Hyaline products of cells* have a tendency to assume a spherical form (Figs. 288, *b*; 293, *d*; 300, *c*, *d*). The disintegration of larger cell-masses with hyaline change leads to the extensive formation of hyaline spherules, strands, or branching structures.

If, in endotheliomata and angiosarcomata, the cord-like masses of cells which have been formed within the lymph- or blood-vessels become converted into hyaline masses, there will be produced formations which greatly resemble glands containing colloid (Fig. 300, *d*); and which have often been mistaken for such.

*Ribbert* regards the melanosaarcoma as an especial form of tumor arising from the chromatophores, and would for this reason separate it from the sarcomata as an individual tumor-type. It is to be noted, however, that in the development of the melanotic sarcoma other cells besides the chromatophores take on proliferative activity: so that melanotic sarcomata can be regarded only as sarcomata in whose development certain cells, which possess the power to form pigment, have taken part.

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## 2. THE EPITHELIAL TUMORS.

### (a) *General Remarks.*

§ 118. The **epithelial tumors** are new growths, in the formation of which both vascular connective tissue and epithelial cells—that is, cells which are derived from either superficial or glandular epithelium—take part. The distribution of epithelium and connective tissue follows in general the normal arrangement of these tissues, the connective tissue either forming a basement structure whose surface is covered with epithelium (skin and mucous membranes), or forming a network or stroma, in the meshes of which the epithelial cells are disposed (glands). The imitation of the first-named structure leads to the formation of **papillary**



FIG. 301.—Papillary epithelioma or ichthyotic wart of the skin (Müller's fluid, hæmatoxylin, eosin). a, Corium; b, enlarged papillary body; c, laminated horny layer.  $\times 40$ .

**new-growths**; that of the second, to the formation of more or less sharply circumscribed **nodules** or to **extensive superficial thickenings of tissue**.

According to the physical characteristics and grouping of the epithelial cells, as well as the clinical behavior of these tumors, epithelial new-growths may be divided into two groups; one group including the

**papillary epitheliomata, adenomata, and cystadenomata**; the other the **carcinomata and cystocarcinomata**. The first group is characterized clinically by the benign character of the growths, *which are sharply circumscribed and form no metastases*. The second group, on the other hand, includes the malignant new-growths, *which grow by infiltration and give rise to metastases*. The two groups, however, are not sharply separated from one another, as papillary epitheliomata and adenomata may, through changes in the mode of reproduction and the manner of spreading of the epithelial cells, become changed into carcinomata.

(b) *Papillary Epithelioma, Adenoma, and Cystadenoma.*

§ 119. A **papillary epithelioma** is a new-growth which is composed of a framework of connective-tissue papillæ covered with epithelial cells. In structure it is therefore similar to the papillæ of the skin; but the papillæ of the new-growth are as a rule higher and often branched, and the epithelial covering thicker.

The **papillary epithelioma** of the skin occurs in the form of *scarty protuberances*, which consist of slender papillæ (Fig. 301) covered with epithelium, the superficial layers of which show marked cornification (*ichthyotic warts and horny warts*). These warts may, like the fleshy warts (see § 109), appear during childhood (*ichthyotic warts*) as well as in old age (*verruca senilis*). The first-named form represents a local mal-



FIG. 302.—Senile horny wart of forehead, from a woman eighty-four years of age (alcohol, hæmatoxylin, eosin). a, Corium; b, epithelium; c, atrophic sebaceous glands with development of horny epithelium in their ducts; d, hypertrophic horny layers; e, enlarged papillæ.  $\times 15$ .

formation of the skin (Fig. 301); while the last-named is due to a pathological proliferation and cornification of the epithelium (Fig. 302, e, d) followed by an outgrowth of the papillæ at the periphery. An excessive cornification of the epithelium over hypertrophic papillæ, giving rise to cylindrical or conical masses of horny cells in which the horny



layers lie at right angles to the surface of the skin, leads to the formation of a *cutaneous horn or cornu cutaneum* (Figs. 123 and 124).

**Papillary epitheliomata of the mucous membranes** occur either in the form of warty, nodular formations (Fig. 303, *e, f*), or in that of long, slender, papillary excrescences (Fig. 304, *a*), which, springing from a narrow base, are often repeatedly branched. The former variety is found especially frequently in the lar-



FIG. 303.

FIG. 303.—Papillary epithelioma of the larynx. *a*, Epiglottis; *b*, ossified cricoid cartilage; *c*, thyroid cartilage; *d*, trachea; *e, f*, papillary proliferations. Natural size.



FIG. 304.

FIG. 304.—Papillary epithelioma of the urinary bladder. *a*, Epithelioma; *b, c*, enlarged prostate; *d*, thickened bladder-wall. Five-sixths natural size.

yux, more rarely in the nose and urinary bladder; the latter most frequently in the urinary bladder and pelvis of the kidney, vaginal portion of the uterus, and more rarely in the ureters, gall-bladder, and biliary passages.

In both cases the excrescences are formed of slender, connective-tissue papillae (Fig. 305) which contain blood-vessels, and are covered by a thick layer of epithelium. The character of the epithelium corresponds in general to that of the part in which the growth occurs, but papillomata covered with stratified squamous cells are sometimes seen in regions which normally possess cylindrical epithelium (nose).

**Papillary epitheliomata in dilatation-cysts**, which are also called **papillary cystomata**, occur most frequently in cysts of the ovary and in cysts of the ducts of the mammary gland, more rarely in *atheromata* (dermoids) of the skin. Within the cyst are formed small, warty elevations or cauliflower-like tumors, which under certain conditions may fill the entire cyst-cavity. Their structure corresponds to that of the



similar excrescences in papillary adenocystomata (see § 121), or the papillary epitheliomata of the skin and mucous membranes.

**Papillary epitheliomata of the surface of the ovary** appear in forms similar to those of the urinary bladder, but are rare. **Papillary epithe-**



FIG. 305.—Papillary epithelioma of the urinary bladder (alcohol, hæmatoxylin, eosin).  $\times 35$ .

**liomata of the cerebral ventricles** take their rise in part from the telæ choroides, and in part from the ependyma.

It is difficult to draw a sharp line between **papillary epitheliomata** and other formations. In particular do those inflammatory proliferations of the skin and mucous membranes—the **pointed condylomata**—which develop especially upon the external genitals under the influence of chronic irritations (compare Fig. 225), so closely resemble the epitheliomata that their inflammatory origin forms the only point of difference. If the connective-tissue framework of the papillary outgrowths is developed to a greater extent than the epithelium, the tumor may be classed with the **papillary fibromata**, and it becomes a question of individual standpoint as to which designation shall be employed. Finally, the benign papillary epitheliomata may pass over into **carcinomata**, either through the growth of the epithelium at the base of the papillæ into the underlying connective tissue, or through the extension of the proliferating surface epithelium upon neighboring organs (as in the case of the papillary epitheliomata of the ovary). In general, it may be said that the designation *epithelioma* is very often applied to *carcinomata* (particularly in France), but it seems more expedient to reserve this term for the benign tumors described above.

Among the epitheliomata may be classed those formations known as **cholesteatomata** or **pearl tumors**, which in part are caused by inflammation, and in part represent misplaced embryonal tissue. The most striking characteristic of the cholesteatoma is the formation of glistening white pearls, which consist of thin, scale-like epithelial cells pressed closely together, and often inclose cholesterin. These tumors are found most frequently in the descending urinary passages, the cavities of the middle ear, and the pia of the brain; very rarely in that of the spinal cord.

Pathological cornifications, with the formation of glistening white scales and pearls, occur in the *urinary passages*, particularly in the course of chronic inflammations. In the *tympanic cavity*, *mastoid antrum*, and *external auditory canal*, the cholesteatomata appear as yellowish-white or bluish-white nodules, varying in size from that of a cherry-stone to that of an egg, and presenting an onion-like laminated structure. Through their pressure upon the neighboring bone they may cause its disappearance. They arise as a product of squamous epithelium which has penetrated from the external ear through openings in the ear-drum into the cavities of the middle ear and has

replaced the cylindrical epithelium, and under especial conditions (chronic inflammations) produces the formations above described. It is probable that in rare cases they arise from epidermoidal cells which during the period of embryonic development have found their way into the cavities in question.

The *intracranial cholesteatomata* are found at the base of the brain (very rarely in the spinal canal), in the region of the olfactory lobe, tuber cinereum, corpus callosum, in the choroid plexus, in the pons, medulla oblongata, and cerebellum. In these regions the cholesteatomata appear on the surface as silk-like, shining nodules of varying size which extend more or less deeply into the brain-substance. The nodules are single, but cholesteatoma-masses may become separated from the chief nodule and displaced into the neighboring tissue. According to *Boström*, it is always possible to demonstrate, at some point, a connection between the pia and the cholesteatoma, where the scales composing the cholesteatoma take their origin from a cell-layer lying upon the vascular connective tissue, the cells of this layer throughout bearing the character of epidermoidal cells. The cholesteatomata of the pia may therefore be designated as *epitheliomata* or as *epidermoids* (*Boström*); and their origin may be explained by the assumption that in the early period of development epidermal germs are misplaced into the anlage of the pia. According to *Boström*, this takes place in the time between the closure of the medullary canal and the separation (by a process of constriction) of the secondary vesicle of the fore-brain from the fore-brain or the 'tween-brain, and the separation of the after-brain vesicle from the hind-brain (fourth to fifth week). These epidermoids may therefore be classed with the teratoid tumors (see Teratoma).

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#### (Cholesteatoma.)

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§ 120. The **adenomata** are usually *nodular tumors* with sharply defined borders; and are situated within glands, or in the skin or mucous

membranes. In the latter situations they not infrequently appear in the form of polypi elevated above the surface. They may occur also in the

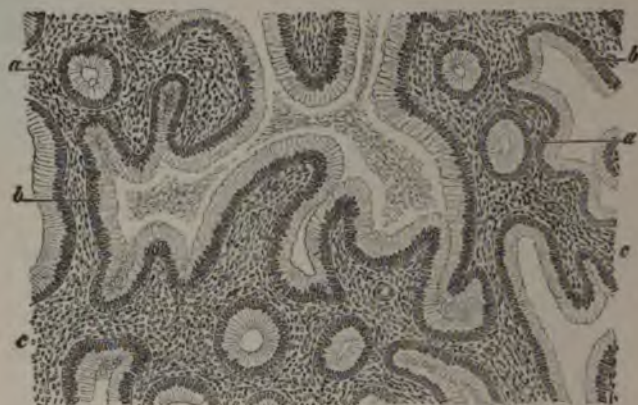


FIG. 306.—Adenoma tubulare (glandular polyp) of the intestine (alcohol, alum-carmin). *a*, Transverse section, *b*, longitudinal section of gland-tubules; *c*, stroma rich in cells.  $\times 10$ .

form of papillary proliferations (Fig. 232). The absence of any tendency to grow by infiltration or to produce metastases stamps these growths as *benign tumors*.

The chief characteristic of the adenoma is the *formation of new glands*, which depart more or less from the typical glands of the affected organ.



FIG. 307.—Adenoma tubulare of the stomach in an atrophic mucosa (formalin, alcohol, hæmatoxylin, eosin). *a*, Mucosa; *b*, muscularis mucosæ; *c*, submucosa; *d*, muscularis; *e*, serosa; *f*, adenoma.  $\times 14$ .

According to their structure adenomata may be classed as *tubular* or *acinous*; but these two forms cannot be sharply separated, the one from



the other. Through the formation of papillary excrescences on the inner walls of the gland-spaces there is formed an *adenoma papilliferum*.

The *stroma* supporting the glands consists in part of preëxisting connective tissue, and in part of that which has been newly formed.

*Adenomata develop either in normal tissue, malformed tissue, in tissues which have been altered by disease* (inflamed mucous membrane, cirrhotic

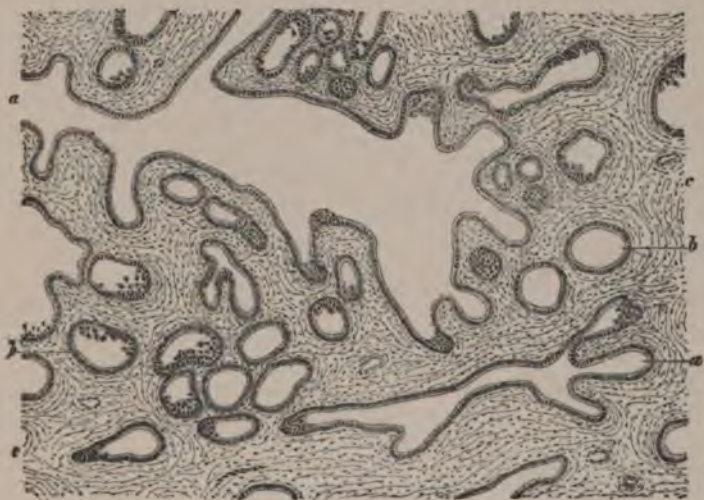


FIG. 308.—Adenoma mammae tubulare (alcohol, alum-carminé). *a*, Branched and dilated glandular spaces cut longitudinally; *b*, same, cut transversely; *c*, stroma.  $\times 27$ .

liver, contracted kidney, ovaries containing scar tissue), or from *remains of fetal structures* (Wolffian body, canalis neurentericus, remains of enamel-germs). The new-formation of glands is dependent upon a pro-

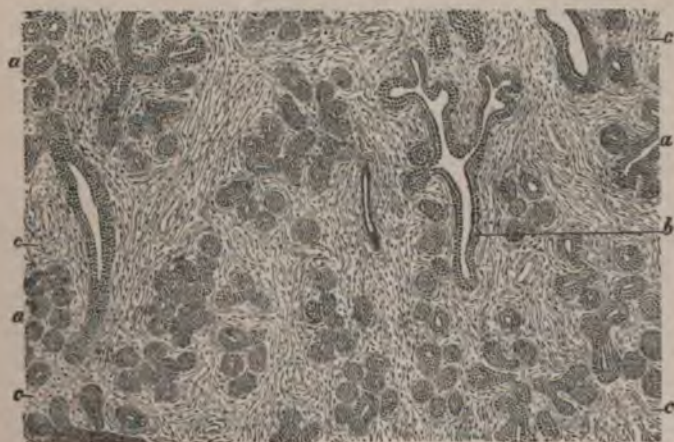


FIG. 309.—Adenoma mammae alveolare (alcohol, alum-carminé). *a*, Terminal alveoli; *b*, gland-ducts; *c*, connective-tissue stroma.  $\times 27$ .

liferation of the surface-epithelium or of glandular epithelium, the steps of this process being similar to those occurring in the regeneration of

normal gland tissue. The cause of the new-formation of gland tissue within normal organs is wholly unknown. Glandular new-formations developing in tissues which have been altered by inflammation, and which lead to tumor-like growths, may in the beginning bear the character of a regenerative or hyperplastic new-formation, and for this reason the adenomata cannot be sharply differentiated from regenerative and hyperplastic proliferations.

**Tubular adenomata** represent the most common form of the adenomata. They occur particularly in mucous membranes (Figs. 306; 307, *f*) provided with tubular glands (intestine, uterus); but are found also in such glands as the breast (Fig. 308), liver, ovary, and not infrequently in the kidneys. They are characterized by the formation of simple and branched gland-tubules (Figs. 306, *a, b*; 307 *f*; and 308, *a, b*) which are lined by simple columnar or cubical epithelium and form nodular tumors varying in size from that of a pea to that of an apple or a man's fist, or rarely even larger.

The **alveolar adenomata** arise from glands (mammary, ovary, thyroid, sebaceous glands); and are characterized by the formation of numerous terminal berry-like alveoli (Fig. 309, *a*), as well as gland-ducts (*b*).

**Papillary adenomata** arise through the formation within the tubules of an adenoma, of little elevations of epithelium into each of which a connective-tissue papilla grows. Through the extensive formation of such papillæ the gland-tubules may become wholly filled or even dilated (Fig. 310, *b, c*).

The **stroma of an adenoma** is at times well developed, at other times but slightly, and consequently adenomata may be divided into *hard* (mammary gland) and *soft varieties* (kidney, liver, ovary, testicle). An

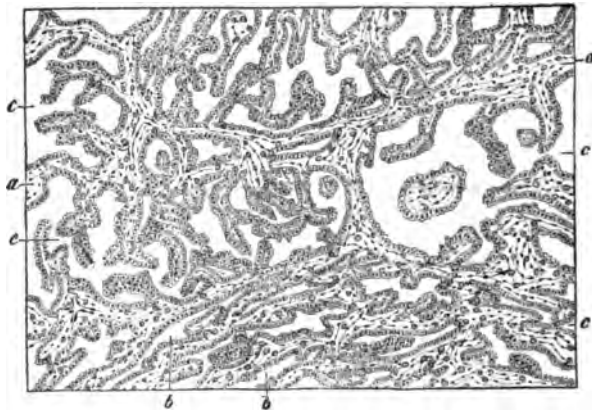


FIG. 310.—Adenoma renum tubulare papilliferum (Müller's fluid, hæmatoxylin). *a*, Connective-tissue stroma; *b*, sinuous gland-tubules; *c*, gland-tubules with marked development of papillary excrescences.

especially marked development of the connective tissue leads to the formation of **fibro-adenomata** or *fibrous adenomata*. Such forms occur most frequently in the mammary gland.

If, as happens not infrequently in the mammary gland, the connective-tissue proliferation in an adenoma is not of a diffuse character but takes place particularly around the canaliculi (see Fig. 241), the tumor



is ordinarily designated as a *fibroma pericanaliculare*. If, as the result of more marked local proliferative activity on the part of the connective tissue (Fig. 311, *c, d, e*), an ingrowth of rather broad and short papillæ



FIG. 311.—Fibroma intracaniculare mammae (fibro-adenoma papilliferum) (alcohol, alum-carmin). *a*, Dense, intercanalicular growth of fibrous tissue; *b*, pericanalicular tissue rich in cells; *c, d, e*, nodular, intracanicular connective-tissue proliferations cut longitudinally; *f*, intracanicular proliferations cut transversely.  $\times 23$ .

(*e*) into the gland-spaces takes place, the resulting tumor is known as a **fibroma intracaniculare**. According to its genesis such a tumor may also be appropriately designated a **fibro-adenoma papilliferum**.

*Adenomata* cannot be sharply differentiated from tumor-like glandular hypertrophies on the one hand, and carcinomata on the other. For example, in the healing of intestinal ulcers the regenerative processes in the glands may be so active as to give rise to polypoid formations, which may either be called *glandular hypertrophies* of the mucous membrane, or *adenomata*, according to the individual standpoint. Likewise, different names may be applied to the glandular polypi which occur so frequently in the uterus.

The *carcinomatous* nature of a new-growth resembling an adenoma (see § 122) is generally made evident by a more marked epithelial proliferation and by its infiltrative mode of growth. There are, however, adenomata, having a single layer of columnar cells, which grow by infiltration (particularly in the intestine), and thereby assume the character of malignant tumors. They should accordingly be classed with the carcinomata, and must be designated either by the term *adenoma destruens* or *adenocarcinoma*. On the other hand, there are also adenomata with marked atypical epithelial proliferation (mammary, endometrium), which—for a long time at least—do not show any malignant characteristics.

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 See also §§ 119 and 121.

§ 121. A **cystadenoma** or **adenocystoma** is an *adenoma whose gland-spaces have undergone cystic dilatation through the accumulation of secretions*.

Such tumors are usually composed of numerous cysts, and are, therefore, designated as **multilocular cystomata**. According to the character of the cyst-wall there may be distinguished a *smooth-walled* or *simple cystoma* (*cystoma simplex*), or a *papilliferous cystoma* (*cystoma papilliferum*).

Small amounts of secretion are often seen in the ordinary adenomata (Fig. 306), and the spaces of both simple and papillary adenomata are often so wide (Figs. 308, *a*; 311) that they at once attract the eye on cross-section of the growth. In cystadenomata such cyst-formation is the predominating feature.

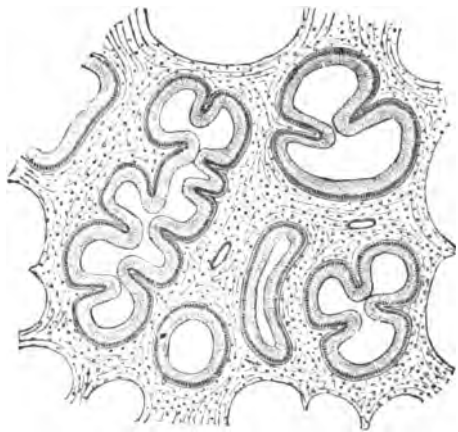


FIG. 312. Section of a cystadenoma ovarii papilliferum (Müller's fluid, hæmatoxylin).  $\times 40$ .

The early stages of the cysts are represented by *gland-tubules* of varying shape (Figs. 312 and 313, *b*), which lie in a more or less richly developed connective-tissue stroma. Through the accumulation of secre-



tion these tubules become gradually dilated so that numerous small cysts arise (Fig. 314), or else both large and small cysts (Figs. 315-319) are

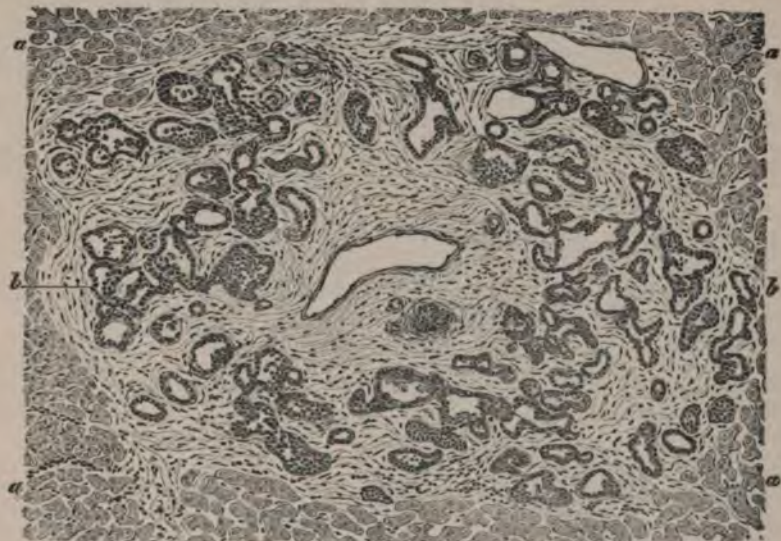


FIG. 313.—Adenocystoma of the bile-passages in the first stages of development (alcohol, hematoxylin). *a*, Liver tissue; *b*, adenoma tissue in the periportal connective tissue.  $\times 90$ .

formed. Often the relationship is such that the tumor may consist of a few large cysts (Fig. 318) in whose walls smaller cysts occur; or there



FIG. 314.



FIG. 315.

FIG. 314.—Section of a portion of a multilocular adenocystoma of the ovary. Reduced about one-sixth.  
FIG. 315.—Section through an adenocystoma of the testis of a four-year-old boy. Natural size.

**papillary epitheliomata, adenomata, and cystadenomata**; the other the **carcinomata and cystocarcinomata**. The first group is characterized clinically by the benign character of the growths, *which are sharply circumscribed and form no metastases*. The second group, on the other hand, includes the malignant new-growths, *which grow by infiltration and give rise to metastases*. The two groups, however, are not sharply separated from one another, as papillary epitheliomata and adenomata may, through changes in the mode of reproduction and the manner of spreading of the epithelial cells, become changed into carcinomata.

(b) *Papillary Epithelioma, Adenoma, and Cystadenoma.*

§ 119. A **papillary epithelioma** is a new-growth which is composed of a framework of connective-tissue papillæ covered with epithelial cells. In structure it is therefore similar to the papillæ of the skin; but the papillæ of the new-growth are as a rule higher and often branched, and the epithelial covering thicker.

The **papillary epithelioma** of the skin occurs in the form of *warty protuberances*, which consist of slender papillæ (Fig. 301) covered with epithelium, the superficial layers of which show marked cornification (*ichthyotic warts and horny warts*). These warts may, like the fleshy warts (see § 109), appear during childhood (*ichthyotic warts*) as well as in old age (*verruca senilis*). The first-named form represents a local mal-

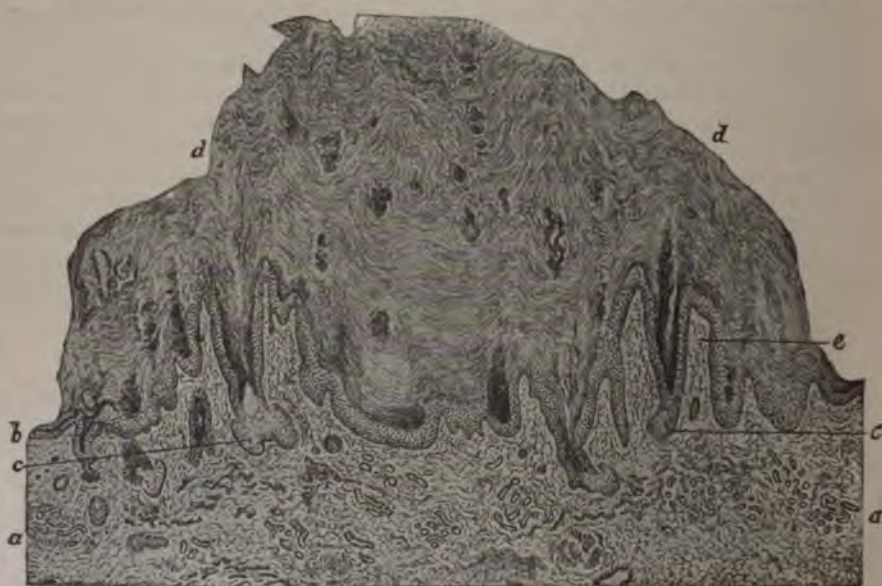


FIG. 302.—Senile horny wart of forehead, from a woman eighty-four years of age (alcohol, hæmatoxylin, eosin). *a*, Corium; *b*, epithelium; *c*, atrophic sebaceous glands with development of horny epithelium in their ducts; *d*, hypertrophic horny layers; *e*, enlarged papillæ.  $\times 15$ .

formation of the skin (Fig. 301); while the last-named is due to a pathological proliferation and cornification of the epithelium (Fig. 302, *c, d*) followed by an outgrowth of the papillæ at the periphery. An excessive cornification of the epithelium over hypertrophic papillæ, giving rise to cylindrical or conical masses of horny cells in which the horny



layers lie at right angles to the surface of the skin, leads to the formation of a *cutaneous horn* or *cornu cutaneum* (Figs. 123 and 124).

**Papillary epitheliomata of the mucous membranes** occur either in the form of warty, nodular formations (Fig. 303, *e, f*), or in that of long, slender, papillary excrecences (Fig. 304, *a*), which, springing from a narrow base, are often repeatedly branched. The former variety is found especially frequently in the lar-



FIG. 303.

FIG. 303.—Papillary epithelioma of the larynx. *a*, Epiglottis; *b*, ossified cricoid cartilage; *c*, thyroid cartilage; *d*, trachea; *e, f*, papillary proliferations. Natural size.



FIG. 304.

FIG. 304.—Papillary epithelioma of the urinary bladder. *a*, Epithelioma; *b, c*, enlarged prostate; *d*, thickened bladder-wall. Five-sixths natural size.

ynx, more rarely in the nose and urinary bladder; the latter most frequently in the urinary bladder and pelvis of the kidney, vaginal portion of the uterus, and more rarely in the ureters, gall-bladder, and biliary passages.

In both cases the excrecences are formed of slender, connective-tissue papillae (Fig. 305) which contain blood-vessels, and are covered by a thick layer of epithelium. The character of the epithelium corresponds in general to that of the part in which the growth occurs, but papillomata covered with stratified squamous cells are sometimes seen in regions which normally possess cylindrical epithelium (nose).

**Papillary epitheliomata in dilatation-cysts**, which are also called **papillary cystomata**, occur most frequently in cysts of the ovary and in cysts of the ducts of the mammary gland, more rarely in *atheromata* (dermoids) of the skin. Within the cyst are formed small, warty elevations or cauliflower-like tumors, which under certain conditions may fill the entire cyst-cavity. Their structure corresponds to that of the



similar excrescences in papillary adenocystomata (see § 121), or the papillary epitheliomata of the skin and mucous membranes.

**Papillary epitheliomata of the surface of the ovary** appear in forms similar to those of the urinary bladder, but are rare. **Papillary epithe-**



FIG. 305.—Papillary epithelioma of the urinary bladder (alcohol, hæmatoxylin, eosin).  $\times 35$ .

**liomata of the cerebral ventricles** take their rise in part from the telæ choroideæ, and in part from the ependyma.

It is difficult to draw a sharp line between **papillary epitheliomata** and other formations. In particular do those inflammatory proliferations of the skin and mucous membranes—the **pointed condylomata**—which develop especially upon the external genitals under the influence of chronic irritations (compare Fig. 225), so closely resemble the epitheliomata that their inflammatory origin forms the only point of difference. If the connective-tissue framework of the papillary outgrowths is developed to a greater extent than the epithelium, the tumor may be classed with the **papillary fibromata**, and it becomes a question of individual standpoint as to which designation shall be employed. Finally, the benign papillary epitheliomata may pass over into **carcinomata**, either through the growth of the epithelium at the base of the papillæ into the underlying connective tissue, or through the extension of the proliferating surface epithelium upon neighboring organs (as in the case of the papillary epitheliomata of the ovary). In general, it may be said that the designation *epithelioma* is very often applied to *carcinomata* (particularly in France), but it seems more expedient to reserve this term for the benign tumors described above.

Among the epitheliomata may be classed those formations known as **cholesteatomata** or **pearl tumors**, which in part are caused by inflammation, and in part represent misplaced embryonal tissue. The most striking characteristic of the cholesteatoma is the formation of glistening white pearls, which consist of thin, scale-like epithelial cells pressed closely together, and often inclose cholesterol. These tumors are found most frequently in the descending urinary passages, the cavities of the middle ear, and the pia of the brain; very rarely in that of the spinal cord.

Pathological cornifications, with the formation of glistening white scales and pearls, occur in the *urinary passages*, particularly in the course of chronic inflammations. In the *tympanic cavity*, *mastoid antrum*, and *external auditory canal*, the cholesteatomata appear as yellowish-white or bluish-white nodules, varying in size from that of a cherry-stone to that of an egg, and presenting an onion-like laminated structure. Through their pressure upon the neighboring bone they may cause its disappearance. They arise as a product of squamous epithelium which has penetrated from the external ear through openings in the ear-drum into the cavities of the middle ear and has

replaced the cylindrical epithelium, and under especial conditions (chronic inflammations) produces the formations above described. It is probable that in rare cases they arise from epidermoidal cells which during the period of embryonic development have found their way into the cavities in question.

The *intracranial cholesteatomata* are found at the base of the brain (very rarely in the spinal canal), in the region of the olfactory lobe, tuber cinereum, corpus callosum, in the choroid plexus, in the pons, medulla oblongata, and cerebellum. In these regions the cholesteatomata appear on the surface as silk-like, shining nodules of varying size which extend more or less deeply into the brain-substance. The nodules are single, but cholesteatoma-masses may become separated from the chief nodule and displaced into the neighboring tissue. According to *Boström*, it is always possible to demonstrate, at some point, a connection between the pia and the cholesteatoma, where the scales composing the cholesteatoma take their origin from a cell-layer lying upon the vascular connective tissue, the cells of this layer throughout bearing the character of epidermoidal cells. The cholesteatomata of the pia may therefore be designated as *epitheliomata* or as *epidermoids* (*Boström*); and their origin may be explained by the assumption that in the early period of development epidermal germs are misplaced into the anlage of the pia. According to *Boström*, this takes place in the time between the closure of the medullary canal and the separation (by a process of constriction) of the secondary vesicle of the fore-brain from the fore-brain or the 'tween-brain, and the separation of the after-brain vesicle from the hind-brain (fourth to fifth week). These epidermoids may therefore be classed with the teratoid tumors (see Teratoma).

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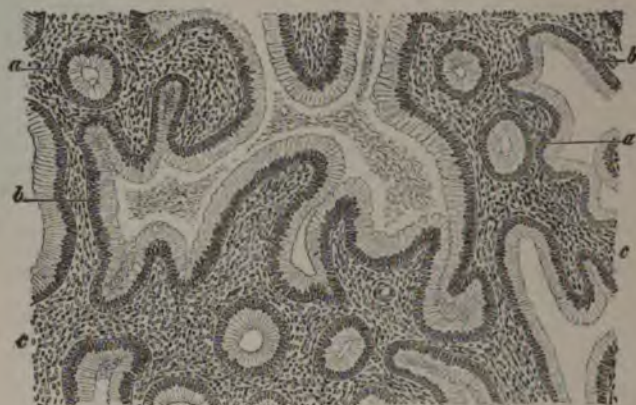


FIG. 306.—Adenoma tubulare (glandular polyp) of the intestine (alcohol, aluin-carmin). *a*, Transverse section, *b*, longitudinal section of gland-tubules; *c*, stroma rich in cells.  $\times 100$ .

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normal gland tissue. The cause of the new-formation of gland tissue within normal organs is wholly unknown. Glandular new-formations developing in tissues which have been altered by inflammation, and which lead to tumor-like growths, may in the beginning bear the character of a regenerative or hyperplastic new-formation, and for this reason the adenomata cannot be sharply differentiated from regenerative and hyperplastic proliferations.

**Tubular adenomata** represent the most common form of the adenomata. They occur particularly in mucous membranes (Figs. 306; 307, *f*) provided with tubular glands (intestine, uterus); but are found also in such glands as the breast (Fig. 308), liver, ovary, and not infrequently in the kidneys. They are characterized by the formation of simple and branched gland-tubules (Figs. 306, *a, b*; 307 *f*; and 308, *a, b*) which are lined by simple columnar or cubical epithelium and form nodular tumors varying in size from that of a pea to that of an apple or a man's fist, or rarely even larger.

The **alveolar adenomata** arise from glands (mamma, ovary, thyroid, sebaceous glands); and are characterized by the formation of numerous terminal berry-like alveoli (Fig. 309, *a*), as well as gland-ducts (*b*).

**Papillary adenomata** arise through the formation within the tubules of an adenoma, of little elevations of epithelium into each of which a connective-tissue papilla grows. Through the extensive formation of such papillæ the gland-tubules may become wholly filled or even dilated (Fig. 310, *b, c*).

The **stroma of an adenoma** is at times well developed, at other times but slightly, and consequently adenomata may be divided into *hard* (mammary gland) and *soft varieties* (kidney, liver, ovary, testicle). An

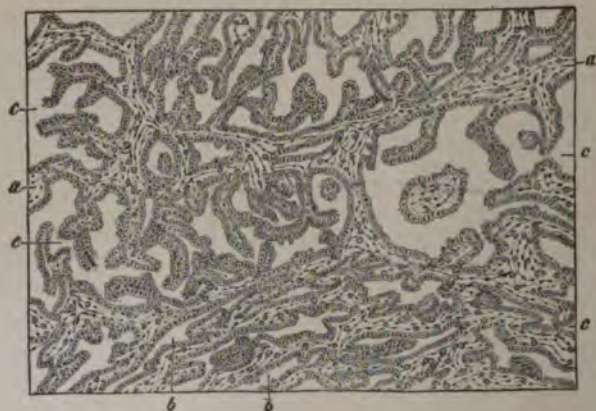


FIG. 310.—Adenoma renum tubulare papilliferum (Möller's fluid, hæmatoxylin). *a*, Connective-tissue stroma; *b*, sinuous gland-tubules; *c*, gland-tubules with marked development of papillary excrescences.  $\times 27$ .

especially marked development of the connective tissue leads to the formation of **fibro-adenomata** or *fibrous adenomata*. Such forms occur most frequently in the mammary gland.

If, as happens not infrequently in the mammary gland, the connective-tissue proliferation in an adenoma is not of a diffuse character but takes place particularly around the canaliculi (see Fig. 241), the tumor



is ordinarily designated as a *fibroma pericanaliculare*. If, as the result of more marked local proliferative activity on the part of the connective tissue (Fig. 311, *c, d, e*), an ingrowth of rather broad and short papillæ



FIG. 311.—Fibroma intracaniculare mammae (fibro-adenoma papilliferum) (alcohol, alum-carmin). *a*, Dense, intercanalicular growth of fibrous tissue; *b*, pericanalicular tissue rich in cells; *c, d, e*, nodular, intracanicular connective-tissue proliferations cut longitudinally; *f*, intracanicular proliferations cut transversely.  $\times 25$ .

(*e*) into the gland-spaces takes place, the resulting tumor is known as a **fibroma intracaniculare**. According to its genesis such a tumor may also be appropriately designated a **fibro-adenoma papilliferum**.

*Adenomata* cannot be sharply differentiated from tumor-like glandular hypertrophies on the one hand, and carcinomata on the other. For example, in the healing of intestinal ulcers the regenerative processes in the glands may be so active as to give rise to polypoid formations, which may either be called *glandular hypertrophies* of the mucous membrane, or *adenomata*, according to the individual standpoint. Likewise, different names may be applied to the glandular polypi which occur so frequently in the uterus.

The *carcinomatous* nature of a new-growth resembling an adenoma (see § 123) is generally made evident by a more marked epithelial proliferation and by its infiltrative mode of growth. There are, however, adenomata, having a single layer of columnar cells, which grow by infiltration (particularly in the intestine), and thereby assume the character of malignant tumors. They should accordingly be classed with the carcinomata, and must be designated either by the term *adenoma destruens* or *adenocarcinoma*. On the other hand, there are also adenomata with marked atypical epithelial proliferation (mammary, endometrium), which—for a long time at least—do not show any malignant characteristics.

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 See also §§ 119 and 121.

§ 121. A **cystadenoma** or **adenocystoma** is an *adenoma whose gland-spaces have undergone cystic dilatation through the accumulation of secretions*.

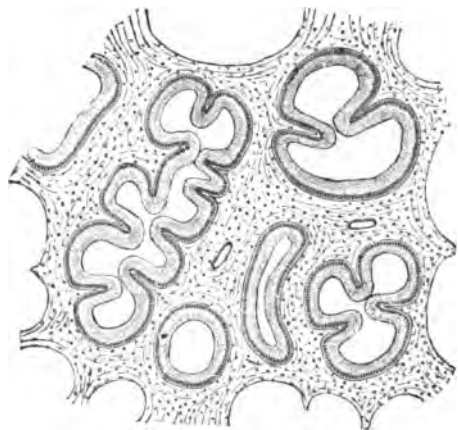


FIG. 312. Section of a cystadenoma ovarii papilliferum (Müller's fluid, hæmatoxylin).  $\times 40$ .

Such tumors are usually composed of numerous cysts, and are, therefore, designated as **multilocular cystomata**. According to the character of the cyst-wall there may be distinguished a *smooth-walled* or *simple cystoma* (*cystoma simplex*), or a *papilliferous cystoma* (*cystoma papilliferum*).

Small amounts of secretion are often seen in the ordinary adenomata (Fig. 306), and the spaces of both simple and papillary adenomata are often so wide (Figs. 308, *a*; 311) that they at once attract the eye on cross-section of the growth. In cystadenomata such cyst-formation is the predominating feature.

The early stages of the cysts are represented by *gland-tubules* of varying shape (Figs. 312 and 313, *b*), which lie in a more or less richly developed connective-tissue stroma. Through the accumulation of secre-



tion these tubules become gradually dilated so that numerous small cysts arise (Fig. 314), or else both large and small cysts (Figs. 315-319) are



FIG. 313.—Adenocystoma of the bile-passages in the first stages of development (alcohol, hematoxylin). *a*, Liver tissue; *b*, adenoma tissue in the periportal connective tissue.  $\times 90$ .

formed. Often the relationship is such that the tumor may consist of a few large cysts (Fig. 318) in whose walls smaller cysts occur; or there



FIG. 314.



FIG. 315.

FIG. 314.—Section of a portion of a multilocular adenocystoma of the ovary. Reduced about one-sixth.  
FIG. 315.—Section through an adenocystoma of the testis of a four-year-old boy. Natural size.



FIG. 316.—Multilocular adenocystoma of the liver, seen in section. *a*, Liver parenchyma; *b*, membranous margin of the left lobe; *c*, *d*, large cysts; *e*, group of smaller cysts, separated from each other only by connective tissue; *f*, portal vein; *g*, hepatic artery. Two-thirds natural size.



FIG. 317.—Cystoma of the kidney, cut transversely. Eleven-fourteenths natural size.



may be found, by the side of large cysts (Fig. 316, *c*), portions of tissue, which contain only small cysts (*e*) or even appear solid—that is, consisting of a tissue the glands of which are not dilated.



FIG. 318.—Adenocystoma ovarii partim simplex, partim papilliferum. *a*, Smooth-walled cysts; *b*, soft papillary growth covered with simple, mucous-forming cylindrical epithellum. (Metastatic nodules were present in the peritoneum.) Reduced one-third.

All the different varieties of cystomata may develop in the ovaries (Figs. 314 and 318), testicles (Fig. 315), liver (Figs. 313 and 316), kidneys (Fig. 317), and the mammary glands.



FIG. 319.—Portion of a papillary adenocystoma of the ovary, seen in section. (Drawn from a specimen hardened in chromic acid.) Four-fifths natural size.

In the ovaries cystomata not infrequently develop coincidently on both sides, and may be associated with dermoid formations. Adenocystomata of the testicles not infrequently inclose within their stroma foci of cartilage or other tissue, so that such growths should be classed with the *teratomata* (§ 129).

The *epithelial lining* of cystomata is usually composed of simple columnar cells, but may be a ciliated, cubical, or flattened epithelium.

The cyst-contents usually consist of a clear, often distinctly ropy fluid, which contains a mucin-like substance (pseudomucin, see § 60). This substance is a product of the epithelial lining in which goblet-cells are often found (Fig. 320, *c*). Not infrequently the fluid also contains whitish flakes, the products of cells which have undergone fatty degeneration; or it may be more or less cloudy or reddish or brownish from previously occurring hæmorrhages. An abundant secretion in many cysts may lead to the formation of tumors of enormous size; in the ovary, for example, they may reach a weight of from ten to twelve kilograms or more.

The **papillary adenocystomata** constitute a common variety of adenocystoma. They are characterized by the fact that sooner or later papillary excrescences develop in the glands which have undergone cystic degeneration.

In the adenocystomata of the ovary these excrescences are usually slender and delicate, forming villous-like outgrowths (Fig. 319) or cauli-



FIG. 320.—Cystoma papilliferum ovarii (Müller's fluid, hæmatoxylin, eosin). *a*, Stroma with papillæ; *b*, gland-tubule with small papillæ; *c*, high cylindrical epithelium; *d*, mucus containing cells, within the cyst-spaces.  $\times 150$ .

flower elevations, which may fill up a larger or smaller part of the cysts. Minute papillary elevations, extending over an extensive area of the inner surface of the cyst-wall, may give to the latter a velvety appear-



ance similar to that of a mucous membrane. If the excrescences develop in cysts of small size, they may fill these, and the tissue may thereby take on the appearance of a dense, non-cystic, medullary tumor, though from the cut surface more or less mucus can usually be obtained.

Larger papillæ are always more or less branched (Fig. 320), and consist of a cellular stroma (*a*), whose surface is usually covered with tall



FIG. 321.—Papillary adenocystoma of the ovary with myxomatous degeneration of the connective tissue of the papillæ (Müller's fluid, hæmatoxylin). *a*, Fibrous stroma; *b*, papillæ which have undergone myxomatous change; *c*, epithelium.  $\times 80$ .

columnar cells (*c*) of the character of goblet-cells. The contents of the cysts consist of ropy mucus (*d*) mingled with more or less numerous desquamated cells which have undergone mucous degeneration, or the remains of such cells. In rare cases the connective tissue of the papillæ may undergo a mucous degeneration (Fig. 321, *a*, *b*), and may swell to a marked degree, and finally become changed into myxomatous spheres covered externally with epithelium.

Adenocystomata of the liver, testicles, and kidneys usually form no papillæ, or at most very small ones. In the papillary adenocystomata of the mammary gland the excrescences are usually broad and plump (Fig. 322), as is the case with those of the papillary adenomata (Fig. 311). Accordingly, on the cross-section of such tumors the cyst-spaces are found to be filled with polypoid proliferations of various forms (Fig. 322), which are often flattened through mutual pressure, and give to the surface of such a cross-section a laminated appearance.

Since in these tumors the connective-tissue elements predominate over the epithelial, these growths are often classed with the *connective-tissue tumors*, and designated, according to the character of the connective tissue, as *cystofibroma*, *cystomyxoma*, or *cystosarcoma*. When showing a structure of leaf-like layers they have received the name of *sarcoma phyllodes*.

The *papillary adenocystomata* show a *certain malignancy*, even when the papillæ are covered with a simple epithelium (see *cystocarcinoma*).

This is shown in the first place, in the fact that the papillary proliferations may break through the cyst-wall, in the case of such tumors of both the ovary and mammary gland, and in the latter situation they may



FIG. 322.—Papillary cystoma or intracanalicular papillary fibroma of the breast, laid open by a longitudinal incision. One-half natural size.

also break through the skin. Papillary ovarian cystomata (Fig. 318, *b*) may in this way give rise to metastases in the peritoneal cavity, and these in turn display the characteristics of papillary epitheliomata.

The *adenocystomata* represent a variety of tumor which possesses no sharply defined limits; for example, papillary cystomata may arise from the development of papillary excrescences in dilatation-cysts which are formed from pre-existing glands (see § 119). Further, malformations of organs—for example, of the kidneys—may lead to the formation of multilocular cystomata, the cystic dilatation affecting not only the urinary tubules, but also *Müller's* capsules. That teratomata may appear in the form of adenocystomata has already been mentioned in the text. Finally, a transition from cystadenoma to cystocarcinoma may also take place.

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(c) *Carcinoma and Cystocarcinoma.*

§ 122. The **carcinomata** are *malignant epithelial tumors* characterized by *infiltrative growth* and the *formation of metastases*.

They develop:

- (1) In the skin, mucous membranes and in glands, all of which appeared to be normal, before the development of the carcinoma.
- (2) In the skin, mucous membranes, and in glands, which have already suffered changes before the development of the carcinoma.
- (3) In already existing papillary epitheliomata, adenomata and adenocystomata.
- (4) From the remains of foetal epithelial structures, and from epithelial tissues which have been misplaced through disturbances of development, and have already developed into pathological formations.
- (5) From the epithelial tissues of the chorionic villi and placenta.

The most essential characteristic of the development of a carcinoma is that presented by **atypical proliferations of epithelium which sooner or later penetrate into the tissue bordering upon the affected glands or surface-epithelium**. This phenomenon is usually accompanied by a **proliferation of connective tissue**; but this is not absolutely essential

to the development of a carcinoma. The tissue invaded by the epithelial proliferation—whether glandular tissue, muscle, bone, etc.—is sooner or later destroyed by the growth.

The **cause of the atypical growth of epithelium** is not known with certainty; it can only be said that certain conditions favor such growth. Thus, for example, *old age* predisposes to the development of carcinomata of the skin, inasmuch as in this period of life the connective tissue of the skin undergoes a certain amount of atrophy and becomes looser in structure, while the epithelium, at least in part, continues to increase, and under certain conditions shows here and there distinct evidences of increased activity (formation of heavier hairs upon the nasal septum, lobes of the ears, and in the eyebrows). Likewise carcinomata of the mucous membranes and the glands usually appear in the later years of life, although they may occur earlier in life, even in childhood.

Further, the *misplacement and separation of epithelium* predisposes to the *formation of cancer*. Such condition may easily happen during the healing of ulcers, and also at the borders or on the surface of both infectious and non-infectious growths of granulation-tissue. Consequently carcinomata not infrequently arise in *ulcers, scars, infective granulomata* (for example, in tuberculous lupus of the skin and mucous membranes), or in *tissues which have been changed by inflammation* of any kind (for example, in a cirrhotic liver).

All these predisposing factors do not constitute the unique cause of the development of a carcinoma. They may exist for a long time without giving rise to a cancer. It appears that something else must be added to cause the unlimited atypical proliferation of epithelium, and what this something is, is at present unknown.

In recent years the opinion has been many times advanced and maintained that **parasites** cause carcinomatous and sarcomatous proliferations. But the majority of the appearances which have been described as parasites (as protozoa, especially sporozoa, and as yeast-fungi) have not been parasites at all, but degenerated nuclei and nuclear division-figures, or leucocytes inclosed within tumor-cells, or degeneration-products of such, or products of cell-protoplasm, particularly keratohyalin and colloid, or epithelial hyalin and mucin. In the few cases in which true parasites were present in the tissues, this occurrence could very well have been a secondary infection, which in no way could be regarded as a cause of the development of the tumor. *In not a single case has it been proved beyond all doubt that parasites have been the cause of either carcinoma or sarcoma.*

Certain portions of the intestinal tract—the rectum, the flexures of the colon, the pylorus and cardia of the stomach, the œsophagus, pharynx, tongue, and gums—are favorite seats for the development of cancer. Cancer may develop in any portion of the skin, but it occurs more frequently on the lips and nose than on the remaining portions of the face, or on the extremities, and on these again more frequently than on the trunk. Of the sexual apparatus the parts most commonly affected are the mammary gland and cervical portion of the uterus; less frequently, though relatively often, the ovary, testicles, body of the uterus, vulva, vagina, and penis. The liver, kidneys, bladder, trachea, bronchi, lungs and pancreas occupy a middle ground; while the larynx and gall-bladder are, on the other hand, more frequently affected.

Cancer usually develops in the form of *nodules, which are not sharply differentiated* from the neighboring tissues; on the mucous membranes

they are not infrequently elevated above the surface in the form of *sponge-like*, or *polypoid*, or *papillary growths*. From the point of origin they spread by an **infiltrative growth** of the epithelial proliferations, by which either the nodules increase in size or there are formed diffuse superficial thickenings, as in the case of the intestinal wall. The ovaries, testicles, uterus, kidneys, etc., may be partly or wholly transformed into carcinomatous tissue. Often the boundaries of the organ originally affected are overstepped, and the epithelial infiltration extends into neighboring tissues and organs. Thus, for example, a carcinoma of the mamma may infiltrate the neighboring fat, skin, and muscle; one of the gums, the maxillary bone; one of the uterus, the vagina, parametrium, bladder, and rectum; a cancer of the gall-bladder may involve the liver; one of the thyroid, the trachea; and one arising in the bronchi, the lungs, etc.

The **formation of metastases** may take place either through the lymph- or blood-vessels, and is of very frequent occurrence by both routes. It leads to the development of secondary nodules in different organs; but it may happen that large lymphatic areas—as, for example, the lymphatics of the lung—may be simply dilated by the new-growth, without the formation of circumscribed nodules. The transportation of cancer-cells to the bone-marrow may lead to a carcinomatous degeneration of the marrow of an entire bone or of several associated bones. Moreover, it should be noted that probably not every transportation of cancer-cells is followed by the development of a cancer, but that many of the cells so transplanted die.

The **tissue of a carcinoma** is sometimes white and soft like marrow, sometimes firm and dense; but it is almost always possible to obtain from the cut surface more or less of a whitish, cloudy fluid called *cancer juice* or *cancer milk*. Very often the cut surface presents a tough, fibrous framework in the meshes of which the softer masses lie; and from which the latter may be squeezed out by pressure either in the form of fluid, or as plugs or as crumbling masses.

The masses obtained from the cut surface through pressure and scraping consist, for the chief part, of **atypically proliferating epithelial cells**, the so-called **cancer-cells**, which are found in a *great variety of forms*, and usually show degenerative changes, particularly fatty degeneration. A true *secretion* of these epithelial cells is usually not found; but cancers occur—particularly in the mucous membranes, ovaries, mammary glands, and thyroid—which produce mucin, pseudo-mucin, or colloid. The amount of secretion may at times be so abundant as to lead to the formation of cysts and thereby to *cystocarcinoma*.

**Retrograde changes** occur very often in cancers at an early stage. They are caused partly by the feeble vitality of the new-growth, partly by circulatory disturbances, which may be due to the filling-up of capillaries and veins by the ingrowing cancer-cells, and partly by external causes. These changes lead, in the first place, to a *destruction of cancer-cells* in certain portions of the tumor, so that, after resorption of the dead material, the tissues often sink in, and in this way depressions are caused over the surface of the tumor-nodules. Such depressed areas are seen particularly upon primary cancer-nodules in the mammary gland, and on secondary nodules in the liver, lungs, and other internal organs, and are often spoken of as *cancer-umbilications*.

The retrograde changes often lead to complete destruction of tumor-tissue, and thereby to the **formation of ulcers**. This occurs particularly

in cancers of the mucous membranes, these growths at the patient's death usually revealing a more or less extensive ulceration; but such ulcerations also take place in carcinomata of the mammary glands and skin. In the latter situation the cancer may take on the appearance of a rodent ulcer. The edge of such ulcers is sometimes elevated and resembles a wall, or it may be studded with nodules; at other times it is more sharply defined and only slightly infiltrated. The base of the ulcer is sometimes fissured and ragged, and covered with necrotic tissue; at other times it is smooth.

The question as to the **etiology of carcinoma and sarcoma** has led in recent years to numerous histological and experimental investigations, and publications in this line have been made by *Sanfelice, Aievoli, Secchi, Plimner, Wlaeff, Sjöbring, Schüller, Curtis, Leopold, Fabre-Domergue, Petersen* and *Exner, Sternberg*, and others. While the earlier writers believed that sporozoa were to be regarded as the cause of carcinoma and sarcoma, recent investigators have sought to prove the etiological relationship of yeasts or rhizopods (*Sjöbring*). Against these views, I believe, in common with *Fabre-Domergue, Sternberg, Petersen*, and *Exner*, that many of the formations which have been described as yeasts were not such, but were cell-products resembling them.

Likewise, the appearances described as protozoa are of a very doubtful nature. *Sjöbring* describes them as very delicate, clear bodies which cannot be fixed; *Schüller*, as large, round, bladder-like bodies of a gold-yellow or brownish color.

The results of attempts at cultivation and of animal experiments have shown only that, outside of the human body, perhaps also by chance in tumors, there are forms of *Saccharomyces* (*Saccharomyces neoformans* of *Sanfelice*), which when injected into animals cause inflammations and proliferations of granulation-tissue, and in part also progressive diseases leading after weeks or months to death. The statements of *Wlaeff, Leopold, Sanfelice*, and others, that they have also produced true tumors, adenomata, adenocarcinomata, carcinomata, and sarcomata, give rise to well-founded doubts concerning the correctness of their interpretations, inasmuch as the appearances described may very well have been inflammatory proliferations within which glands have also proliferated (intestinal glands, bile-ducts). The assertion of *Leopold* that he had been able, through the injection, into the testicle of a rat, of yeasts cultivated from an ovarian cancer, to produce a giant-celled sarcoma in the form of multiple nodules in the peritoneal cavity of the animal, can hardly be taken as evidence of the parasitic nature of cancer. Likewise, the statement of *Sjöbring* that he had been able to produce in four mice, by means of rhizopods, a cylindrical-celled and squamous-celled carcinoma, a colloid cystoma, and an adenoma of the sebaceous glands respectively, is of no value, because of the meagreness and inaccuracy of his description.

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§ 123. The development of carcinoma of the skin takes place most often from the *surface epithelium*, and is characterized essentially by the growth of the interpapillary portions of the same into the deeper portions of the skin, in the form of epithelial plugs (Fig. 323, *d*) which fill up the connective-tissue spaces. The stratum corneum (*c*) may also undergo hypertrophy along with the cells of the rete Malpighii, and penetrate into the deeper tissues with the epithelial plugs (*d*). Moreover, the horny cells which get into the deeper tissues may form epithelial pearls (*e*).

Besides the surface-epithelium, the *epithelium of the hair-follicles* and *sebaceous glands* may also take part in the development of the cancer; and there occur carcinomata of the skin, which develop entirely from

the sebaceous glands, and therefore should be classed with the gland-cancers.

The *connective tissue* may remain entirely passive during the ingrowth of the epithelium, but is sooner or later excited to growth (Fig. 324, *a*), and the papillæ often develop into long, branched formations (*f*). In

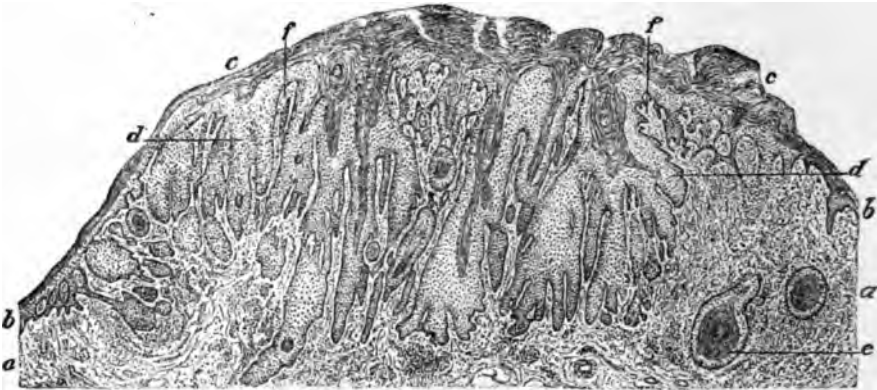


FIG. 323.—Transverse section through a carcinoma of the lip (alcohol, hæmatoxylin, eosin). *a*, Corium, in a state of proliferation; *b*, epithelium; *c*, thickened horny layer; *d*, epithelial plugs extending into the corium; *e*, epithelial plugs with horny pearls, cut obliquely; *f*, enlarged papillæ.  $\times 12$ .

the proliferating connective tissue there are often found in association with the *fibroblasts* also *leucocytes*, which may penetrate into the epithelium. They become especially numerous in the event of tissue-destruction, so that under such circumstances the proliferation of the connective tissue acquires wholly the character of an inflammatory granulation tissue.

The origin of the carcinomata arising from mucous membranes covered with squamous epithelium may be the same as that of a cancer of the skin—that is, it is introduced by a proliferation of the surface epithelium (Fig. 324, *a*, *c*). If glands are present they may also take part in the development of the cancer. It is a remarkable fact that in the formation of such a tumor, glands with cylindrical epithelium may furnish epithelial products which correspond with those of the surface-epithelium. The epithelial proliferation may at first be intracanalicular and lead to a diffuse thickening and stratification of the epithelium (Fig. 324, *f*), or to the formation of excrescences (*e*). Later, the proliferating epithelium breaks into the connective tissue.

The connective tissue behaves in the same manner as in the case of cancer of the skin.

The cylindrical-celled carcinomata of the mucous membranes arise in the case of the intestine from the *tubular glands* or from the *crypts*, the epithelium of which at first undergoes an active proliferation, and becomes stratified, while the glands become dilated (Fig. 325, *b*). Later, the glands become changed into branching, atypically formed structures (*c*), which possess an epithelium arranged in many layers, and which grow into the neighboring tissues.

In the stomach the gastric glands change their character (Fig. 326, *f*), and then through a continued growth infiltrate the submucosa (*g*), the muscularis (*d*), and the serosa (*e*).

The epithelium of the newly-formed glands stains more deeply with nuclear stains than does normal epithelium.

The connective tissue, as in the case of *cancer* of the skin, sooner or later proliferates, and in connection with this proliferation there may occur also an emigration of leucocytes.

The **development of cancer in glands**—as, for example, in the mammary gland—likewise begins with an *epithelial proliferation*, as the result of which the glands (Fig. 327, *a*) become widened, altered in form (*b*), while their lining epithelium becomes stratified (*b*). With the breaking through of the epithelium into the neighboring connective-tissue spaces, the epithelial infiltration of that tissue is begun. According to the structure of the gland in which the cancer arises, and according to the



FIG. 324.—Beginning development of carcinoma in the vaginal portion of the uterus (alcohol, Bismarck-brown). *a*, Epithelium; *b*, connective tissue; *c*, surface epithelium growing into the deeper tissues; *d*, dilated glands; *e*, glandular epithelium growing out in form of plugs; *f*, cross-section of a gland, the cylindrical epithelium of which has become converted into stratified epithelium.  $\times 45$ .

variety of the cancer itself, there will be produced varying microscopical pictures.

The *connective tissue* of the gland through proliferation also takes part in the building-up of the tumor; but in the early stages of development such proliferation may be slight or entirely wanting.

The **development of a carcinoma in an adenoma** or fibro-adenoma



(Fig. 328, *a*) is likewise initiated by a *more active proliferation of the epithelium*, through which the simple epithelium becomes stratified (*b*, *c*).



FIG. 325.—Developing adenocarcinoma of the large intestine (Müller's fluid, hæmatoxylin, eosin). *a*, Mucosa with unchanged glands; *b*, glands showing carcinomatous change; *c*, carcinomatous areas in the submucosa.  $\times 100$ .

The later ingrowth of the epithelium into the connective tissue, which often occurs at a very late stage, is a further sign of malignancy—that is, of the carcinomatous transformation of the new-growth.



FIG. 326.—Adenocarcinoma of stomach in process of development (formalin, alcohol, hæmatoxylin, eosin). *a*, Mucosa; *b*, muscularis mucosæ; *c*, submucosa; *d*, muscularis; *e*, serosa; *f*, *g*, adenocarcinoma.  $\times 15$ .

The development of carcinoma from papillary epitheliomata takes place in the same manner as from the normal skin and mucous mem-



branes; and is characterized especially by the infiltration of the epithelium into the basement-tissue upon which the epithelioma rests.



FIG. 327.—Developing cystocarcinoma of mamma (alcohol, hematoxylin). Tumor of the size of a bean. *a*, Normal gland-tissue; *b*, proliferating gland-tissue.  $\times 100$ .



FIG. 328.—Tubular adenoma of mamma showing a beginning transition to carcinoma (formalin, hematoxylin). *a*, Branching gland-tubules with simple epithelium; the pericanalicular connective tissue is proliferating and very cellular; *b*, *c*, gland-tubules, the epithelium of which is partly simple, partly stratified.  $\times 100$ .



The development of carcinoma from transplanted or misplaced epithelium or from remains of fetal structures proceeds in the same manner as that of carcinomata arising in either surface or glandular epithelium.

**Carcinomatous proliferations of chorionic or placental villi** may arise either from the fetal *ectodermal epithelium* of the chorion and its villi, or from the cells known as the *syncytium* which are situated upon the former, or from both. They grow from the point of attachment of the villi into the neighboring uterine tissue, particularly into the blood-vessels of the uterus (Fig. 329, *d, d<sub>1</sub>, c, f, h*), and may through the formation of thrombi lead to extensive destruction of the tissues of the uterus, and may give rise to metastases. Myxomatous degeneration of the chorion

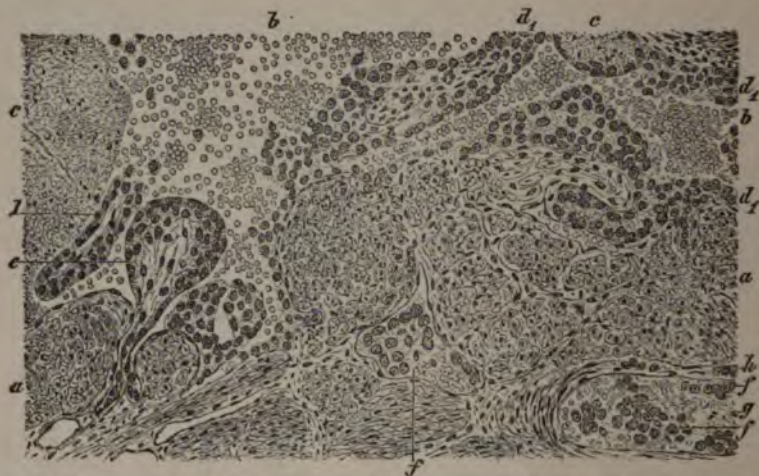


FIG. 329.—Carcinoma placentaire of the uterus (compare von Kahliden, *loc. cit.*). *a*, Muscularis of the uterus; *b*, large venous blood-spaces; *c*, thrombus; *d, d<sub>1</sub>*, intravascular proliferations of the epithelium of the chorionic villi into a large blood-space, opened from the uterine cavity, and containing thrombi; these proliferations are either free (*d*) or lie in part upon the vessel-wall (*d<sub>1</sub>*); *e*, proliferating cell-masses, which have forced their way into a smaller vessel; *f*, collections of proliferating chorionic epithelium within the veins of the uterine musculature; *g*, thrombus; *h*, proliferating cells in the vein-wall.  $\times 70$ .

or placental villi (hydatid mole) appears to favor the development of such carcinomatous growths. These proliferations may be appropriately designated *placental* and *chorionic carcinomata*. They have been frequently described under the names of *malignant placentoma*, *deciduoma*, *chorioepithelioma*, *malignant placental polyp*, etc.

**Adenomata** and **carcinomata** cannot always be sharply differentiated from each other, for the reason that tubular adenomata, especially of the intestine, more rarely of the thyroid or liver, although possessing a simple cylindrical epithelium, may grow by infiltration, break into the surrounding tissues, and produce metastases. If an especial name is to be applied to such growths to distinguish them from the ordinary carcinoma adenomatosum or adenocarcinoma, the designation **adenoma destruens** or **malignum** or **carcinomatosum** may be used. Further, it should be noted that benign adenomata, which have existed as such for a long time, may pass over into carcinomata.

Carcinomata arising in the skin or mucous membranes are often called **cancroids**, a term used to distinguish them from other carcinomata, the origin of which was formerly thought to be from connective tissue.

To a certain extent the character of the parent tissue is preserved in cancer cells, but a careful examination shows in all cases that there is a certain amount of change both in their morphological and in their physiological character (*anaplasia*). This is shown in changes in the form and structure of the cells, their changed behavior toward

stains, in an altered position and arrangement of the cells, and in their changed relations toward the surrounding tissues.

The traumatic displacement of surface-epithelium in wounds may lead to the formation of the so-called **traumatic epithelial cysts**—that is, cysts varying in size from that of a hemp-seed to that of a nut, which are lined with epithelium, and, in case they arise from the epidermis, contain a pultaceous mass of desquamated epithelium. They occur most frequently after puncture-wounds of the volar surface of the fingers and in the hollow of the hand.

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 See also § 124.

(*Traumatic Epithelial Cysts.*)

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§ 124. The **structure of a carcinoma** is determined by its origin. The manner in which the epithelium proliferates and the associated pro-

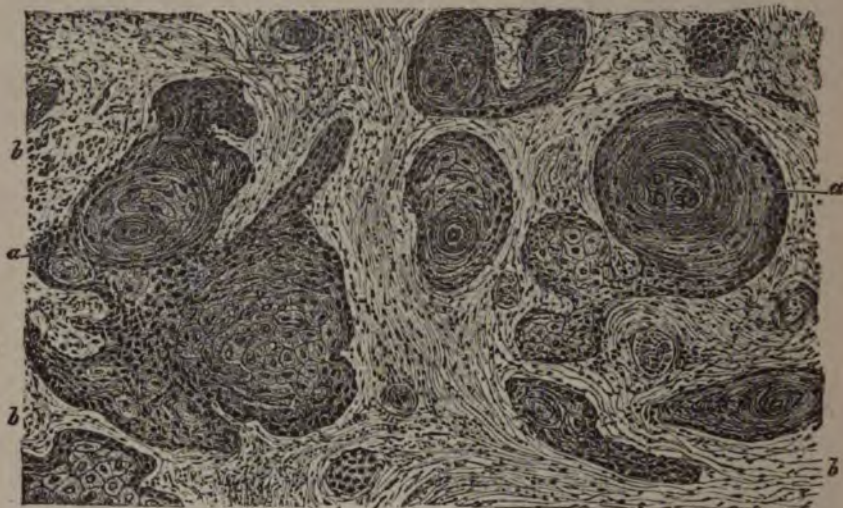


FIG. 330.—Horny cancer of the tongue (Müller's fluid, hæmatoxylin, eosin). *a*, Epithelial plugs with epithelial pearls; *b*, stroma.  $\times 100$ .

liferation of the connective tissue make it possible to distinguish a **connective-tissue stroma** which contains the blood-vessels, and **nests** and



FIG. 331.—Epithelial plug from a carcinoma of the skin.  $\times 250$ .

**strands of cells**—the so-called **cancer-plugs**—which lie embedded in the stroma. If the cancer grows into a tissue having a special structure, the stroma may contain muscle-fibres, bone trabeculae, unchanged glandular tissue, etc.; but these tissues usually die after a time. In general a carcinoma possesses an **alveolar structure**, at times suggesting an imperfectly developed acinous gland, at other times a tubular gland, so that it is possible to distinguish **acinous** and **tubular** types of carcinoma. When the cell-plugs are solid, without a lumen,



the growth may be called a **carcinoma solidum** or merely **carcinoma**. The presence of a lumen in the cell-plugs gives to the growth an appear-



FIG. 332.—Adenocarcinoma recti tubulare (alcohol, alum-carmin). *a, b*, Epithelial gland-tubules; *c, c*, stroma; *d*, collections of leucocytes in the gland-tubules.  $\times 65$ .

ance resembling anatomically the adenomata, and warrants the designation **carcinoma adenomatosum** or **adenocarcinoma** (Figs. 325–327).

According to the character of the epithelial cells and of the cell-

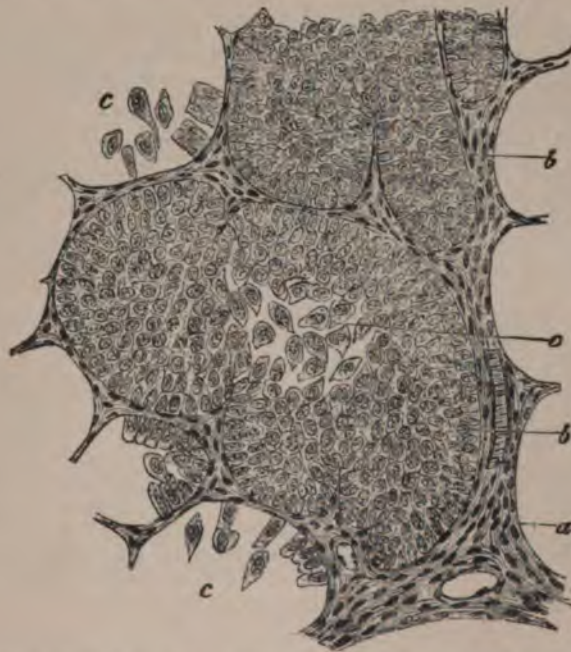


FIG. 333.—Adenocarcinoma fundi uteri. *a*, Stroma; *b*, cancer-plugs; *c*, isolated cancer-cells.  $\times 150$ .

groups formed by them, as well as the nature of the secondary changes occurring in them, there may be distinguished a number of **varieties of**

**carcinomata.** Since the character of the cells is dependent upon the parent-tissue, certain types of carcinoma are characteristic for certain regions of the body, and appear almost exclusively in these parts.

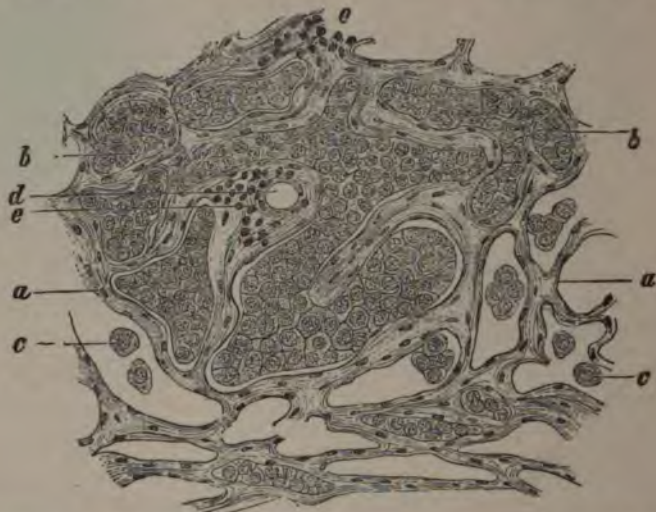


FIG. 334.—Carcinoma simplex mammae (alcohol, hæmatoxylin). *a*, Stroma; *b*, cancer-plugs; *c*, isolated cancer-cells; *d*, blood-vessels; *e*, small-celled infiltration of the stroma.  $\times 200$ .

(1) **Squamous-celled cancers** develop in the **skin** and in those **mucous membranes covered with squamous cells**. They occur, therefore, in the external skin, mouth cavity, pharynx, œsophagus, larynx, vaginal portion of the cervix, vagina, and external genitals. In rare cases they

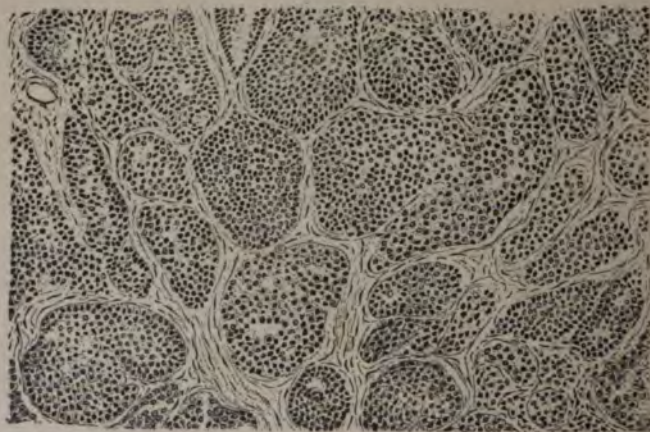


FIG. 335.—Acinous carcinoma of the mammary gland with large nests of cells (Müller's fluid, hæmatoxylin).  $\times 100$ .

may develop in mucous membranes possessing cylindrical epithelium—for example, in the trachea—or in the remains of foetal structures—for example, in the remains of the branchial clefts, and in dermoids; finally also in the ependyma of the cerebral ventricles.



The flat-celled cancer is characterized chiefly by the formation of relatively large cell-nests (Figs. 330, *a*; 331) of irregular shape; but they often form also small strands of cells, particularly in the case of spreading cancers of the mucous membranes. The epithelial cells which are collected in masses show clearly the character of stratified squamous epithelium, but on account of their multiplication within the tissue-spaces are usually *polymorphous* (Fig. 331), and no longer manifest their typical characteristics. Very often the formation of keratohyalin and cornification takes place within the large epithelial plugs which have penetrated into the deeper tissues. The cells which have undergone a horny change become arranged in concentric laminae resembling those of an onion (Figs. 323, *e*; 330, *a*; 331). Such cell-nests are known as *epithelial pearls* or *horny bodies*, and give occasion for the designation of the tumor as a *horny cancer*.

Ordinarily the **cell-plugs** of a squamous-celled cancer are **solid**, but not infrequently **gland-like epithelial proliferations** are formed, in



FIG. 333.—Tubular scirrhus cancer of the mammary gland (Müller's fluid, hematoxylin). *a*, Spot at which there are well-developed oblong nests of cells; *b*, portion of tumor in which the cell-nests have for the greater part disappeared.  $\times 100$ .

which a central lumen and an epithelial wall may be distinguished, the former usually containing necrotic cells and masses of detritus. According to Krompecher this happens especially when in the development of the cancer the epithelial proliferation is limited to the columnar cell-layer of the rete Malpighii.

(2) **Cylindrical-celled carcinomata** develop chiefly in those mucous membranes possessing cylindrical epithelium—intestines, stomach, respiratory tract, body of the uterus, and gall-bladder, but occur also in glands—ovary, mammary gland, liver, etc.—as well as in the cerebral ventricles. Such tumors exhibit, at least in the early stages of development, the character of **carcinoma adenomatosum** or **adenocarcinoma** (Figs. 325, 326, 332, 333); and also form epithelial structures which resemble glands and consist of variously-formed gland-tubules lined by a simple or stratified epithelium. A more active proliferation of the epithelial cells leads finally to the formation of compact cell-nests possessing no lumen (Fig. 333).

The stroma of cylindrical-celled carcinomata is usually poorly developed; and the tumor consequently bears the character of a soft cancer, a **carcinoma medullare**. Nevertheless the cancerous tissue may in some cases possess a firm consistence.

(3) The **carcinoma simplex** or *carcinoma in the narrower sense*—that is, a cancer whose especial characteristics are derived from the form and position of the cancer-cells, in that these are arranged simply in irregular, compact heaps (*carcinoma solidum*)—occurs most frequently in glands, but may develop also in the mucous membranes and skin. The cell-nests are in part very irregularly shaped (Fig. 334), in part round (Fig. 335), or in other cases elongated or fusiform (Fig. 336). These variations have given occasion to the employment of the terms **carcino-**



FIG. 337.—Section through a segment of a carcinoma of the breast (alcohol, hæmatoxylin). *a*, Nipple; *b*, tissue of gland; *c*, skin; *d*, gland-ducts; *e*, carcinomatous masses occupying the place of the gland tissue; *f*, carcinomatous infiltration of fat tissue; *g*, portion of skin infiltrated with carcinoma; *h*, nests of cancer-cells in the nipple; *i*, normal gland-lobule; *k*, small-celled infiltration of the connective tissue. Magnified by hand-lens.

**ma acinosum** (Fig. 335) and **carcinoma tubulare** (Fig. 336) as distinguishing types of corresponding character. It should be noted, however, that these different types may be present in the same tumor (Fig. 337, *e, f, g*), since the character of the cell-nests depends partly upon their manner of growth and partly upon that of the connective-tissue stroma in which they develop. At the seat of origin of the tumor the cell-nests may have a variety of shapes (*e*); in adipose tissue they are rounded (*f*); in the unyielding connective tissue of the skin they are small and fusiform (*g*).

An abundant development of cell-nests within a delicate connective-tissue stroma leads to the formation of a **carcinoma medullare**. A marked development of the connective-tissue stroma with the formation of relatively few cancer-cells gives rise to a hard tumor, which is called a **carcinoma durum** or a **scirrhus** (Fig. 336).



The hard variety of cancer owes its origin to the fact that the cell-nests are from the beginning relatively few and small, while the connective

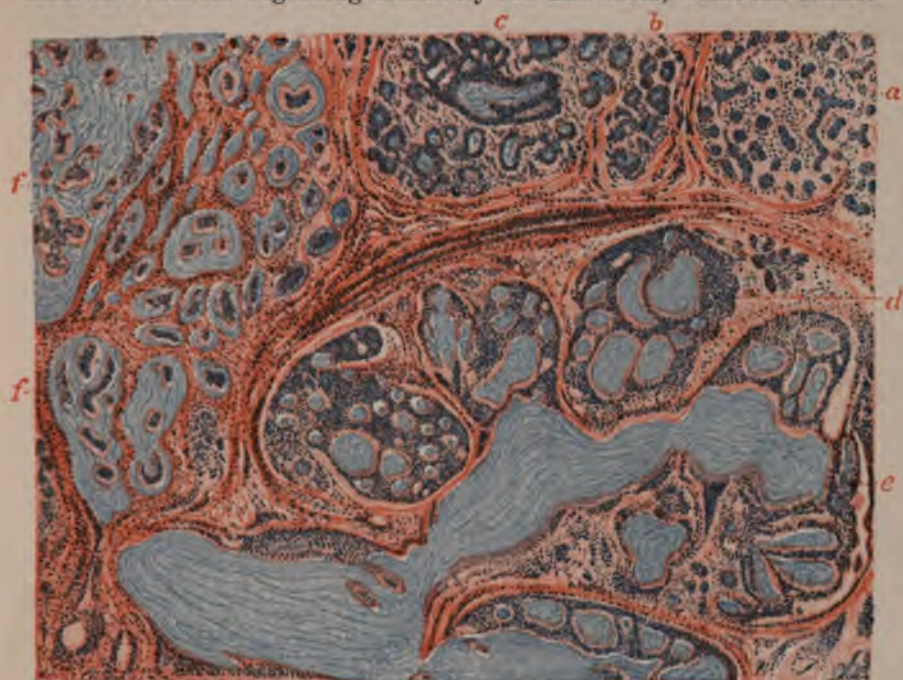


FIG. 338.—Mucoid carcinoma of the mammary gland (Müller's fluid, haematoxylin, eosin). *a*, Normal gland tissue; *b*, *c*, early stages of carcinomatous proliferation with beginning formation of mucus; *d*, larger cell-nests with masses of mucus; *e*, *f*, carcinoma tissue showing marked mucous degeneration.  $\times 50$ .

tive-tissue stroma is abundant and hard. Such tumors are formed especially when the epithelial proliferation infiltrates into hard connective



FIG. 339.—Early stages of development of a mucoid carcinoma of stomach, arising in an atrophic mucosa (formalin, alcohol, haematoxylin, eosin). *a*, mucosa; *b*, muscularis mucosae; *c*, submucosa; *d*, muscularis; *e*, serosa; *f*, *g*, Mucoid cancer.  $\times 9$ .

tissue, as, for example, in the mammary gland and skin, but the same characteristics may be exhibited in the case of newly-formed connective

tissue. In the course of time a cancer becomes harder by reason of the destruction of a large portion or of all of the nests of epithelial cells (Fig. 336, *b*), while the connective tissue increases in amount. An originally

soft cancer may become hard through a more or less pronounced shrinkage of the cancerous tissue in association with the induration of the tissue. Carcinomata of the mammary gland, stomach, and intestine very often show such secondary hardening, and in cancer tissue which has undergone such a fibrous change the nests of cancer-cells may be entirely absent.



FIG. 340.—Carcinoma mucosum mammae (alcohol, hæmatoxylin). *a*, Stroma; *b*, cancer-plugs; *c*, alveoli without cancer-cells; *d*, cells containing spherules of mucus.  $\times 200$ .

(4) **Cancers characterized by peculiar secondary changes** arise through the formation of especial products by the cancer cells, or through peculiar metamorphoses of the same, or more rarely through changes in the stroma.

**Mucoid or gelatinous cancer—carcinoma mucosum** (*C. gelatinosum*, *C. colloides*)—is that form of carcinoma in which the epithelial cells produce mucus (mucin or pseudomucin) or a more colloid-like gelatinous substance. Such production of mucus occurs particularly in cancers of the intestine, stomach (Fig. 339), and mammary gland (Fig. 338); and may be manifest in the earliest stages of the development of the tumor (Figs. 338, *b*, *c*; 339, *f*, *g*), so that the mucoid products of the cells collect first in the centre of the cell-nests after the manner of a gland secretion. Later the border of cells surrounding the mucoid material is broken through, the cells pushed aside, separated from the underlying structures, and crowded toward the centre of the mucus-containing alveolus (Fig. 338, *d*, *e*, *f*). Ultimately, the epithelial cells are wholly destroyed.

In intestinal cancers the formation of mucin takes place in goblet-cells, which are similar to the goblet-cells occurring under normal conditions. In cancer of the breast the mucus appears in the form of droplets within the cancer-cells (Fig. 340, *d*), and becomes free either by escaping from the cell, or through the complete destruction of the cell itself.

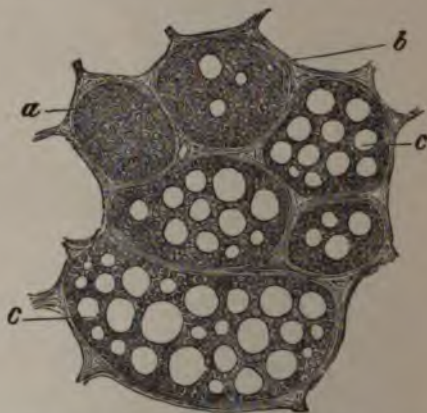


FIG. 341.—Carcinoma with hyaline drops within the cell-nests (Carcinoma cylindromatosum). *a*, Cell-nest without; *b*, cell-nest with a few hyaline spherules; *c*, cells which have been reduced to strands arranged in a network, as the result of the formation of numerous hyaline spherules.  $\times 150$ .



Through the development of mucoid or colloid-like masses within the cancer-cell nests, the latter may become studded with hyaline drops, and thereby acquire a mesh-like appearance (Fig. 341). Such formations were formerly designated as *cylindromata*, and classified with the corresponding sarcomata. Should it be thought desirable to retain this nomenclature, such a tumor may be designated *carcinoma cylindromatosum*; but it seems unnecessary to separate these growths from the mucoid and colloid carcinomata.

When the cancer-cells attain an extraordinarily large size, as occurs, for example, in flat-celled cancers or in cancers of the breast, the tumor may be termed a **carcinoma gigantocellulare**.

If the enlargement of the cells is not due to an increase in the amount of protoplasm, but to a swollen condition of the cells or to a collection of drops of fluid in the cells and their nuclei (Fig. 342), the cells are designated *physalides* (*carcinoma physaliferum*).

*Myxomatous degeneration of the connective-tissue stroma* may occur in portions of a cancer, so that the cancer-cells become separated from each other by myxomatous tissue (Fig. 343). Such growths may be called *carcinoma myxomatosum*.

**Hyaline degeneration of the connective tissue** occurs in different forms of cancer, but is usually confined to small areas of the tumor.



FIG. 342.—Enlarged hydropic cancer-cells, from a carcinoma of the mamma (Müller's fluid, Bismarck-brown). *a*, Ordinary cancer-cells; *b*, hydropic cells containing drops of fluid; *c*, swollen nucleus; *d*, swollen nucleolus; *e*, wandering cells.  $\times 300$ .

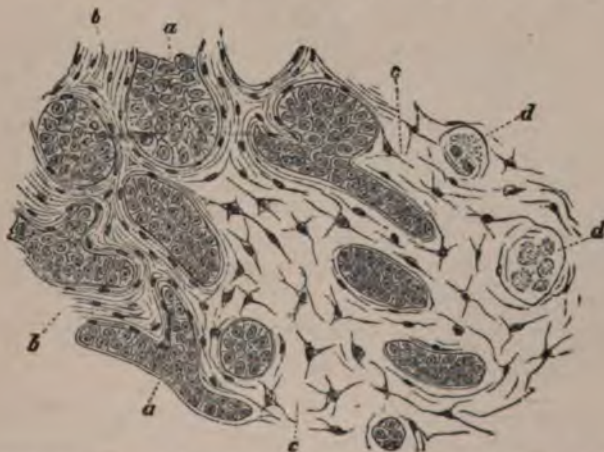


FIG. 343.—Carcinoma myxomatodes ventriculi (Müller's fluid, hæmatoxylin). *a*, Cancer-plugs; *b*, connective-tissue stroma; *c*, stroma of myxomatous tissue; *d*, cancer-cells which have undergone mucous degeneration.  $\times 200$ .

**Deposits of lime-salts** in carcinomata occur chiefly as concretion-like masses, similar to those found in psammomata. The concretions may form either from the cells or in the connective tissue. They are observed

particularly in papillary adenomata and carcinomata of the ovary, and in cancers of the mammary gland. There also occur more extensive calcifications, which may lead to complete **petrification**; and tumors showing such changes occur chiefly in the skin and subcutaneous tissues, in



FIG. 344.—Adenosarcoma malignum of the kidney, from a child seven years of age (formalin, hamatoxylin, eosin). *a*, Tissue with gland-tubules; *b*, sarcoma-like tissue.  $\times 300$ .

the form of sharply defined, hard, rounded nodules. Some of these tumors, according to the descriptions given, are to be classed with the carcinomata, others represent calcified atheromata or adenomata of the sebaceous glands.

If, at the same time with development of the epithelial new-growth, there occurs a marked proliferation of the connective tissue, leading to the formation of a very cellular tissue, there arise tumors which, according to their structure, may be designated **adenosarcoma** or **sarcocarcinoma**. Typical examples of this form of tumor occur in the kidneys (Fig. 344, *a*, *b*), forming medullary tumors, the origin of which is probably to be referred to a disturbance of development of the kidney. Such tumors may show a varying structure in different parts, at one time more of an adenomatous or carcinomatous character, at another time only a sarcomatous. The metastases of such tumors exhibit a similar character.

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 See also §§ 123 and 125.

§ 125. The **cystocarcinomata** represent a form of tumor which stands in the same relation to cancer as the cystadenomata do to the adenomata. The majority of cancers form no demonstrable secretion, but there occur certain varieties, particularly in the group of adenocarcinomata, in which the epithelial cells produce mucus or colloid (thyroid); and in adenocarcinomata of the liver a secretion of bile has been observed (Schmidt). In cystocarcinomata the mucous secretion of the epithelium may lead to the formation of large spaces filled with fluid. Cystocarcinomata occur chiefly in the ovary and mammary gland, usually bearing the character of a **cystocarcinoma papilliferum** (Fig. 345), in that the cyst-spaces, in certain parts or throughout, are either partially (*b, c*) or wholly (*d, e*) filled with papillary proliferations. These excrescences



FIG. 345.—Cystocarcinoma papilliferum mammae. *a*, Stroma; *b*, smooth-walled cysts; *c*, cysts containing papillary proliferations; *d*, cysts entirely filled with papillary proliferations; *e*, small, encysted papillary growths; *f*, adenomatous proliferations; *g*, papilla of the mamma. Reduced about one-third.

possess a soft, medullary appearance, and when developed in great numbers give to the entire tumor a marrow-like character.

Both the cyst-wall and the papillary proliferations, which branch in the same manner as do those of the papillary cystadenomata, are covered with a thick, stratified layer of epithelium (Fig. 346, *b, c, d*; 347, *e*).

The papillæ are usually slender (Fig. 346, *c*, *d*), but through *myxomatous degeneration* of their connective tissue may attain a large size (Fig. 347,

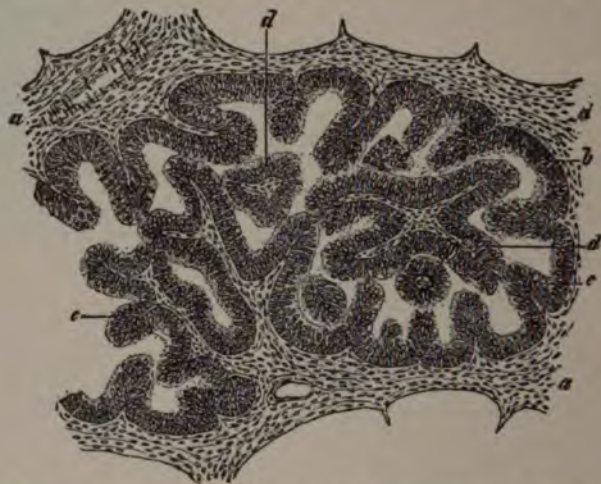


FIG. 346.—Cystocarcinoma papilliferum ovarii (Müller's fluid, hæmatoxylin). *a*, Stroma; *b*, epithelium; *c*, *d*, papillæ.  $\times 72$ .

*b*). Through total *myxomatous degeneration* of the connective tissue of the papillæ the latter may ultimately become converted into *mucous cysts* surrounded by epithelium. If at the same time the epithelial layers of



FIG. 347.—Papillary cystocarcinoma of the mamma with papillæ which have undergone *myxomatous degeneration* (Müller's fluid, hæmatoxylin, eosin). *a*, Dense connective tissue; *b*, myxomatous papillæ; *c*, proliferating epithelium, arranged in several layers.  $\times 73$ .

neighboring papillæ become confluent, the epithelium finally comes to represent a stroma which incloses balls of mucus.



The metastases of cystocarcinomata may have the character of cauli-flower-like, papillary growths, and this is particularly the case when ovarian tumors of this nature spread throughout the peritoneal cavity. Other metastases show the characteristics of ordinary carcinomata.

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 See also § 123.

§ 126. **Growth by infiltration and the involvement of the surrounding tissues** takes place, during the early stages of development (Sec. 123), through the penetration of the epithelial elements alone into the neighboring tissue; but it also happens that in the growth of a tumor into neighboring organs, the connective-tissue stroma (Fig. 348, *d*) surround-

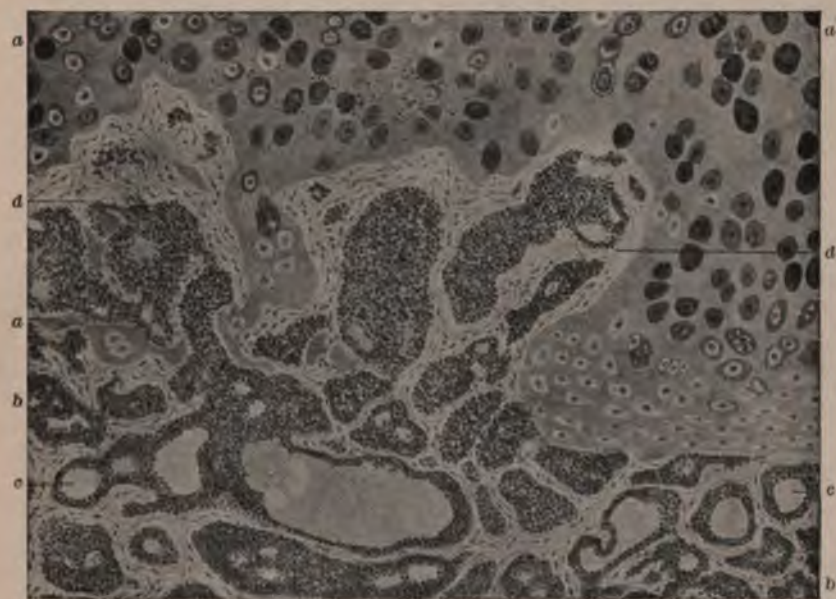


FIG. 348.—Colloid-containing cancer of thyroid infiltrating the thyroid cartilage (alcohol, hæmatoxylin, eosin). *a*, Cartilage; *b*, cancer-tissue; *c*, colloid; *d*, cancer-tissue growing into the cartilage.  $\times 85$ .

ing the cell-nests breaks into the neighboring tissue (*a*) and replaces it. Such a mode of infiltration occurs to the most marked degree in the case of carcinomatous infiltration of cartilage (*a*) and bones.

The **formation of metastases**, which takes place more frequently in the case of carcinoma than any other form of tumor, is the natural result of its infiltrative mode of growth. In the process of infiltration the

*cancer-cells break into the lymph-vessels* (Fig. 235), and through these are carried to the lymph-glands. In both places there results a multiplication of the transported cancer-cells (Figs. 235; 349, *d*). In the lymph-glands the lymphadenoid tissue becomes replaced by cancer tissue; the lymphocytes vanish, while the connective tissue of the lymph-gland serves as a framework for the cancer.

The development of cancer in the lymph-channels is either limited to the filling and distention of the lymph-vessels by the cancer-cells (Fig. 235) or it may likewise lead to the formation in this situation of daughter-nodules.

The epithelial obstruction of the lymph-vessels is often very extensive; and through the blocking-up of individual lymph-channels or of the thoracic duct itself, a *retrograde metastasis of cancer-cells may be caused*. For example, in the case of a cancer of the stomach the lymph-vessels of the mesentery or of the lungs, or even of the upper extremities, may become the seat of metastatic growths.

The *epithelial proliferation breaks into blood-vessels* not less frequently than into the lymphatics; and the invasion of the veins by cancer-cells is to be regarded as a constant phenomenon. In consequence the vessel-lumen becomes filled with cancer-cells, and at a later stage the affected portion of the vessel becomes converted into cancer-tissue, the framework of which is formed through the proliferation of the constituents of the more or less altered vessel-wall. The transportation of cancer-cells

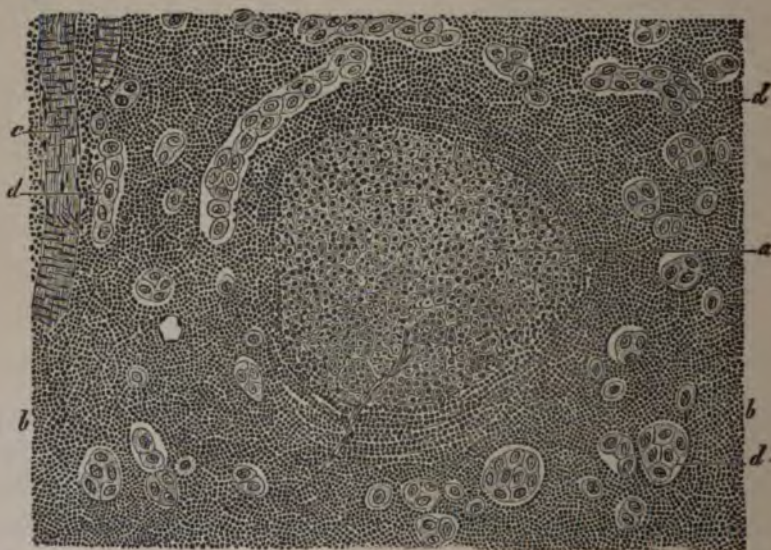


FIG. 349.—Section from an enlarged axillary gland, with beginning development of cancer (alcohol, hæmatoxylin). *a*, Germ-centre of a lymph-node; *b*, lymph-sinuses; *c*, artery; *d*, nests of cancer-cells.  $\times 60$ .

which have been set free in the blood-stream leads to the formation of metastases (Figs. 236, *b*; 350; 351). Here also the cancer growth proceeds primarily from the transported epithelial cells; later a stroma for the cancer-nodule is furnished by the vessel-walls (Fig. 351) and the adjacent structures.



The daughter-nodules grow partly by expansion and partly by an appositional growth through the infiltration of the neighboring blood-vessels and lymph-spaces.

In general the cancer-metastases retain a nodular form. In the serous membranes and in the skin diffuse proliferations of tissue may occur,

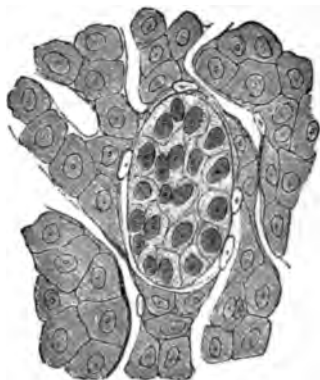


FIG. 350.

FIG. 350.—Metastatic collection of young cancer-cells within a liver-capillary, arising from a primary adenocarcinoma of the stomach (alcohol, hæmatoxylin).  $\times 300$ .



FIG. 351.

FIG. 351.—Metastatic development of cancer within the liver-capillaries, arising from a primary carcinoma of the pancreas (alcohol, carmine). Both connective tissue and nests of carcinoma cells have developed within the capillaries.  $\times 250$ .

leading to dense thickenings which inclose only small cancer-nodules. Likewise, the bone-marrow of entire bones or groups of bones may present a diffuse carcinomatosis, in which process there is formed in the place of the bone a cancer-tissue, the stroma of which not infrequently contains newly-formed osteoid tissue.

Portions of living cancer-tissue when transplanted from one animal to another of the same species may continue to grow and form daughter-nodules, in the same manner as in the formation of metastases in the individual originally affected.

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 See also § 102.

### 3. THE TERATOID TUMORS AND CYSTS.

§ 127. Under the head of **teratoid tumors and cysts** may be grouped those tumor-like formations which are characterized by the fact that the

tissue-formations of which they are composed either do not occur normally at the site in question (*heterotopous growth*), or at least do not normally appear there at the time at which they are found (*heterochronous growth*). Part of the teratoid tumors and cysts, which are classed as **teratomata** in the narrower sense, exhibit, moreover, the peculiarity that they are composed of a variety of tissues.

The teratoid tumors and cysts may be conveniently divided, according to their structure and their origin, into three groups, as follows:

- (1) *The simple teratoid tumors;*
- (2) *the simple teratoid cysts;* (3) *the complex teratomata, which in part contain tissues derived from all the germ-layers.* In the last-mentioned class there may further be distinguished certain forms which occur particularly in the sexual glands.

The **heterotopous tissue-growths**, which are classed with the teratoid tumors, may occur in the most various organs, but are more frequently found in certain regions than in others. Among the more common tumors of this class are the chondromata and chondromyxomata of the salivary glands and the testicle, osteomata of the muscles, lipomata of the pia mater, adenosarcomata of the kidney containing striped muscle, and the adrenal tumors found in the kidney. Among those occurring more rarely are the chondromata and osteomata of the skin or of the mammary gland, rhabdomyomata of the testicle, etc.

The occurrence of tissue-formations in regions in which such tissues are not normally present can be explained in part by the assumption that **cells or groups of cells** of a tissue have not under-

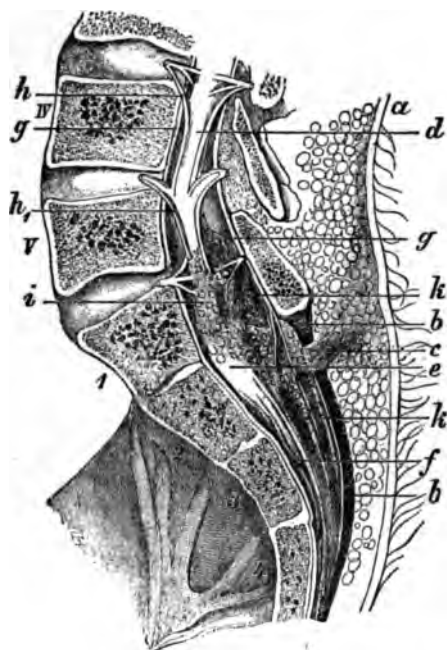


FIG. 352.—Spina bifida occulta with myelipoma inside of the spinal canal. (Sagittal section about 1 cm. to the left of the median line. Reduced about one-half. Taken from von Recklinghausen.) *a*, Abnormally hairy skin; *b*, fibrous covering forming the dorsal wall of the sacral canal, with a slit-like opening at *c*; *d*, spinal cord; *e*, conus medullaris, lying in the second sacral vertebra (*2*) instead of in the second lumbar vertebra; *f*, cauda equina; *g*, dura mater; *h*, *h*<sub>1</sub>, recurrent left anterior nerve-roots of the third and fourth lumbar nerves; *i*, fat tissue; *k*, strands of muscle; *IV*, fourth lumbar vertebra; *V*, fifth lumbar vertebra; *1-4*, sacral vertebrae.

dergone a normal differentiation into definite tissue-forms, but **retain the capacity of forming different kinds of tissues**. Nevertheless, in many cases the explanation is to be sought rather in a **germinal aberration** or a **misplacement of tissue**, in that either in early embryonic life embryonal cells of one organ find their way into the anlage of another organ, or that later, tissues in process of development or already formed are displaced from their normal position. The first process can be inferred only from the subsequent appearance of pathological tissue-formations; the latter, on the other hand, may at times be recognized, later on, in the anatomical relations. Thus, for example, in the retrograde changes occurring in hernias of the sacral portion of the spinal

cord adipose tissue (Fig. 352, *i*) and muscle-tissue (*k*) may find their way into the spinal canal and the arachnoideal sac and grow around the nerves. Arnold observed transposition of fat-tissue, gland-tissue, cartilage and neuroglia at the lower end of the trunk, in a case of myelocyst with complete absence of the lumbar, sacral, and coccygeal portions of the spinal column. He also found in a lipomatous teratoma of the frontal region that the intracranial portion of the tumor communicated with the extracranial through a defect in the cranium.

The **teratoid cysts** may be divided into two great groups: the *ectodermal* on the one hand, and the *entodermal* and *mesodermal epithelial cysts* on the other.

The **ectodermal cysts** vary in size from that of a pea to that of a man's fist. Their walls present ectodermal characteristics, either in that they consist only of a smooth connective-tissue membrane, covered with stratified squamous cells—the so-called **epidermoids**; or the cyst walls may present all the characteristics of skin—that is, contain papillæ, sebaceous glands, hair follicles, hairs and sweat-glands, and often also subcutaneous fat—the so-called **dermoids** or **dermoid cysts** or **dermatocysts**.

The cyst-contents consist either of desquamated horny cells alone, or of such cells, fat, and blond hair.

**Epidermoids** and **dermoids** are found chiefly in the *skin* and *subcutaneous tissues*, where they present themselves in the form of *tumors containing a pulsatous material*, which resemble *atheromata*, i.e., tumors caused by the retention of secretion in the excretory ducts of the sebaceous glands and in the hair-follicles. They are also found at the sides of the neck and in the median line either above or below the hyoid bone; further, in the *thoracic cavity*, particularly in the *mediastinum*, in the *peritoneal cavity* (rarely), *pelvic cellular tissue*, *coccygeal region*, and in the *raphé of the perineum*. Finally, they also appear *within the cranium*, in the *dura* or in the *hypophysis*. Of frequent occurrence are the intracranial formations which are known as **cholesteatoma** or as **pearl tumors**. These growths vary in size from that of a pea to that of an apple; they form spherical or nodular tumors, having a white satiny surface, and consist for the chief part of thin, non-nucleated, scale-like cells, arranged in closely crowded laminae. They are invariably situated at some point on the pia (Boström), and at such places the vascular pia is covered with stratified squamous cells, which in the course of years produce the delicate epithelial scales of which the tumor is composed. The neighboring brain tissue and the arachnoid, which may in part extend over the growth, are not concerned in the formation of the horny scales. In rare cases cholesteatomata may contain *sebaceous material* and *fine hairs* in addition to the horny scales and cholesterol. In these cases there may be found seated here and there upon the pia *dermal structures*, i.e., true skin tissue containing *sebaceous glands* and *hair-follicles*, from which the sebaceous material and hairs found in the growth arise. The simple cholesteatomata may therefore be designated as **epidermoids** (Boström), those containing hair as **dermoids**. Cholesteatomata occur at the base of the brain, in the neighborhood of the olfactory lobe, tuber cinereum, corpus callosum, choroid plexus, pons, medulla oblongata (very rarely in the spinal cord), and in the cerebellum.

The dermoids and epidermoids under consideration doubtless owe their origin to a **transplantation of epithelial germs** to the sites in question. In the case of the epidermoids probably only embryonal epithelial cells are transplanted; in dermoids embryonal dermal tissue is

also transplanted. The intracranial cholesteatomata originated probably in an early implantation of epidermal anlage in the pia. Mediastinal dermoids probably depend upon disturbances of development of the thymus, which arises from the ectoderm. The dermoids on the sides of the neck arise from remains of the branchial clefts, particularly of the



FIG. 353.—Adenoma-like isolation in the submucosa of a portion of the mucous membrane of the small intestine, giving rise to a ridge-like prominence of the mucosa 2 cm. in length (alcohol, hæmatoxylin). From a child six weeks of age. *a, b, c*, Normal intestinal wall; *d, e*, portions of mucosa included within the submucosa; *f*, mucous tissue rich in cells.  $\times 35$ .

second; those hanging from the hyoid bone or lying beneath it are probably to be regarded as the remains of the ductus thyreoglossus. Dermoids of the pelvic cellular tissue may be explained as arising from epithelial inshoots from the perineum.

Simple **entodermal** and **mesodermal epithelial cysts** are characterized by a lining of cylindrical cells, which are often *ciliated*. They occur most frequently in the broad ligament and tubes. They are found also in other portions of the peritoneal cavity, in the intestine, in the neighborhood of the trachea and bronchi, in the lungs, pleura, neck, tongue, glandular organs, etc. They form cysts varying in size from that of a pin-head to that of a man's head.

The occurrence of these cysts may be explained in most cases by the **persistence of foetal glands or canals** or by the **separation through constriction of portions of entodermal or mesodermal epithelial tubes**. In the neck remains of the internal branchial clefts, in the posterior portions of the tongue the remains of the ductus thyreoglossus or of epithelial buds and glands developing from the same (Schmidt), in the œsophagus and respiratory tract snared-off portions of the intestinal canal or of the air-passages, or remains of the communication between alimentary tract and air-passages, may form the foundation for the development of such cysts. In the broad ligament, uterus wall, and tubes the cysts arise from remains of the canals of the Wolffian body and the duct



of Gärtner; in the cervix, portio vaginalis, vagina, and hymen they arise from the remains of the latter; in the peritoneal cavity in part from snared-off portions of the intestine (*enterocysts*), or in part from portions of the urachus (*urachus-cysts*). Within the glands—for example, the liver or the kidneys—portions of the gland-tubules may become constricted off during the period of development, and later develop into cysts (*adenocysts*).

Cysts located in the central nervous system or its immediate neighborhood—for example, at the lower end of the trunk—may arise from the medullary canal (*myelocysts*).

The origin of the cysts lined with cylindrical epithelium can usually be determined only from their position and the character of their walls, but in the majority of cases the origin can usually be ascertained beyond doubt. The diagnosis can be made with the greatest certainty when the misplacement of the separated portion is slight (Fig. 353, *d, e*), and when the formation still shows clearly the character of the mother-tissue.

The significance of ectodermal, entodermal, and mesodermal cysts is dependent upon their position, size, and the secondary changes which occur in them. Their size varies from that of a pin-head to that of a man's head. Among the *secondary changes*—aside from *inflammation*—may be mentioned the development of *adenomata* and *carcinomata*. For example, remains of the Wolffian body which are present in the dorsal wall of the uterus near the angles of the tubes (von Recklinghausen), or



FIG. 354.—Adenoma-like remains of the Wolffian body, within the uterine musculature (formalin, alcohol, hæmatoxylin, eosin). *a*, Muscle tissue; *b*, glandular tissue; *c*, sections of vessels.  $\times 100$ .

in the broad ligament in the inguinal region (Aschoff, Pick) may give rise to adenomata, cystadenomata (Fig. 354, *b*), or adenomyomata. *Dermoids* may be the seat of development of a *squamous-celled cancer* (branchiogenic and subcutaneous carcinoma); while from separated portions of the intestinal mucous membrane (Fig. 353) it is probable that cylindrical-

celled carcinomata may take their origin. *Cysts, cystadenomata, and carcinomata* may develop in the jaw from misplaced portions of the *epithelial anlage of the teeth*.

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- See also §§ 128 and 147.

§ 128. **Teratoid cysts of a complicated structure and solid teratomata** are found, outside of the sexual glands, in the same regions as the simple teratoid cysts, but show a particular predilection for the region of the coccyx. The complex character of the *cysts* is shown by the presence in the cyst-wall of cartilage, bone, fat tissue, mucous glands, smooth and striped muscle fibres, nerve-tissue, and tissue of a sarcomatous or carcinomatous nature. Dermoid cysts may also contain teeth, and further also ciliated epithelial cysts. The *solid teratomata* occur, in the first place, as *hairy polypi* (nose, throat, and mouth)—that is, as polypoid tumors covered with hairy skin, and consisting essentially of adipose tissue, which may also contain muscle fibres, cartilage, bones, teeth, and cysts. Another group consists of those *kidney-tumors* which, in addition to tubular glands, inclose sarcomatous tissue, cartilage, fibrous tissue, adipose tissue, and muscle tissue, in rare cases also ectodermal tissues. In the *vagina* and *cervix uteri* of children there occur tumors, for the greater part of a racemose character, which, in addition to connective tissue, myxomatous tissue, round and spindle-celled tissue, also contain smooth and striped muscle-fibres, and in rare cases also cartilage. Finally, there occur tumor-like growths of a very complicated structure in

the *cranium, thorax, abdomen, neck, lower jaw*, and especially in the region of the *coccyx*. They contain the most varied forms of tissue: connective tissue, adipose tissue, cartilage, bone, gland tissue, muscle, nerve and brain substance, as well as ectodermal and entodermal cysts. They may further inclose rudimentary, or completely formed, or at least easily recognizable, portions of the body.

Both the complex teratoid cysts and the solid teratomata are in many cases to be regarded as **local disturbances of development** characterized by a **misplacement of tissue** or a **separation of tissues by constriction within a single individual** (*monogerminal tissue-implantation, autochthonous teratoma*). The hairy polypi of the throat, the cystic or solid teratomata at the base of the skull or in the hypophysis may be explained by the assumption of a misplacement of ectodermal tissue. The presence of cartilage and mucous glands in teratoid cysts of the mediastinum may be explained by the proximity of the trachea. The teratoid mixed tumors of the kidney may be explained by the assumption that in the kidney region, in addition to kidney-tubules and remains of the Wolffian body, products of the mesenchyma arising from the myotome may undergo proliferation. The occurrence of squamous-celled formations in such tumors must depend upon the fact that ectodermal tissue has found its way into the kidney anlage. The presence of striped muscle-fibres of cartilage in tumors of the vagina and uterus is explainable by the assumption of an implantation of myotome or of anlage of the vertebræ (sclerotome); but many writers hold the opinion that striped muscle may be formed from unstriped. Wilms believes that the Wolffian duct and its development give occasion to and are the cause of the implantations into the cervix and vagina. In the case of the teratomata of the coccygeal region the manifold character of these growths may be explained by the fact that portions of the terminal vertebræ, of the pelvis, and of muscular tissue, as well as remains of the neuroenteric canal, the hind-gut, and the medullary canal, take part in the formation of the tumor. In the intracranial teratomata, as well as in the simple dermoids, tissue-implantations probably form the basis for the growth. Moreover, there exists indeed the possibility of another mode of origin for these growths—namely, the presence of a **rudimentary twin, a bigerminal implantation**. Such an assumption is well founded in all those cases in which the teratoma contains fully developed or rudimentary parts of the body, or tissue-formations which cannot be explained by the assumption of a misplacement of the tissue elements of a single foetus at the spot in question. Ekehorn regards the complex dermoids of the mediastinum, which contain skin, cartilage, bone, and the constituents of mucous membranes, as bigerminal implantations. Lexer emphasizes such a mode of origin for the teratoid mixed tumors of the abdominal cavity (see §§ 129, 132, and 147).

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See also §§ 127 and 147.

§ 129. The **teratomata of the ovary and testicle** occur partly in the form of dermoid cysts, and partly as solid tumors in which multiple cystic formations are present. The dermoid cysts are found chiefly in the ovary; the solid tumors in the testicle.

The so-called **dermoid cysts** of the ovary form rather thick-walled cysts, varying in size from that of a pea to that of a man's head, and are filled with a fatty material containing blond hair. At some point in the wall there will be found extending into the cyst-cavity a *villus-like, nodular, flattened, or septum-like prominence, which is covered with hairs and*

often studded with teeth (Fig. 355, *b*, *c*, *d*). The upper layers of this prominence contain the characteristic structures of the skin (Fig. 356, *a*, *a*, *a*, *b*), namely, hair-follicles with hairs, sebaceous glands, and sweat-glands; subcutaneous fat is also usually present (*f*). In the deeper layers are found other tissue-formations, such as cysts and tubes lined with ciliated columnar epithelium (*d*), bone (*g*), cartilage, teeth (*h*),



FIG. 355.—Portion of the wall of a dermoid cyst of the ovary. *a*, Smooth wall; *b*, prominence consisting of fat and cutaneous tissues; *c*, swollen protuberance, bent down upon itself above and bearing hairs and teeth (*d*). Natural size.

muscle-tissue (also heart-muscle [Katsurada]), brain-tissue (*i*), nerves, groups of ganglion-cells, mucous glands, intestinal mucosa, and thyroid tissue, as well as pigmented formations resembling the rudimentary tissues of the eye. Kidney and liver tissues have not yet been found. The remaining portion of the cyst-wall of the dermoid is either covered with cylindrical epithelium or is bare; if hairs are present in this portion, they are the result of a secondary implantation, and may be surrounded by granulation-tissue, often also by giant-cells. If in association with the cysts containing fat and hairs there are also found cysts filled with a serous or mucoid fluid, the latter may be explained as arising through the cystic dilatation of spaces of the dermoid which are lined with cylindrical cells. More frequently, however, they represent formations resulting from the cystic degeneration of neighboring ovarian follicles or of adenomatous new-growths. The ovary may be entirely destroyed by the dermoid; but remains of its tissues are often present (*k*). In very rare cases several dermoids may develop coincidentally in one ovary; a double-sided occurrence is seen in about fifteen per cent. of all cases.

Ovarian dermoids are observed most frequently in individuals of middle age, but occur also in children.

The most characteristic feature of ovarian dermoids lies in the fact that they contain *elements of all three germ-layers*, and that a certain law in the arrangement of the different elements is observed. The derivatives of the ectoderm and mesoderm, in particular the skin and its appendages, also bone and teeth, and often brain substance, are developed to the most marked extent; while entodermal formations, cylindrical-celled tubules, and mucous glands are ordinarily developed to a much less degree, and lie concealed in the deeper parts of the growth. The structure of the growth as a whole gives the impression of a *rudimentary embryo* with an unequal development of ecto- and entodermal tissue, and



FIG. 356.—Section through a prominence in a multilocular dermoid (alcohol, nitric acid, hematoxylin, eosin). *a, a<sub>1</sub>, a<sub>2</sub>*, Epidermis; *b*, corium with sebaceous glands; *c*, sinus lined with squamous epithelium; *d*, sinus lined with cylindrical epithelium; *e*, tubular glands; *f*, fat-tissue; *g*, bone; *h*, teeth; *i*, brain-tissue with corpora amylacea; *k*, ovarian tissue.  $\times 5$ .

such tumors have therefore been appropriately designated as **embryomata** (Wilms).

The **solid teratomata** of the ovary are much more rare than the dermoid cysts. They form tumors which are composed of a confused mixture of the most varied tissue-formations, viz., epidermis, epithelial



pearls, hairs, sebaceous glands, sweat glands, tubules, and cysts lined with columnar cells, acinous glands, connective tissue rich in cells, adipose tissue, muscle, cartilage, and bone. In rare cases teeth, intestine, thyroid and brain tissue of a rudimentary character may be present.

Since these formations also contain *elements of all three germ-layers*, and are distinguishable from the dermoids only through the lack of any regular order of arrangement of the different tissues, and through the more rudimentary development of the individual tissues, they may likewise be classed with the **embryomata**. With reference to their lack of any structural organization approaching that of the human embryo, Wilms has designated these formations as *embryoid tumors*.

Since the embryoma contains elements of all three germ-layers, in part in orderly arrangement, the genesis of such a tumor may be explained by the assumption of a *development from an ovum*. Wilms and others believe that the development of an unfertilized ovum may be assumed; but nothing is known concerning parthogenetic development



FIG. 357.—Congenital adenocystoma (teratoma) of the testicle with pigmentation and formation of cartilage (Müller's fluid, hæmatoxylin). *a*, Connective-tissue stroma; *b*, simple cubical epithelium; *c*, stratified cylindrical epithelium; *d*, stratified ciliated cylindrical epithelium; *e*, pigmented epithelium lining gland-tubule; *f*, pigmented connective-tissue cells; *g*, cartilage in connective tissue; *h*, cartilage lying in a gland-tubule. (Section taken from tumor pictured in Fig. 315.)  $\times 100$ .

of the ova of mammals, and the occurrence of such seems very improbable. Bonnet regards it as much more probable, that either in the development of a fertilized ovum, in the early stages of division, a blastomere (or several) may be delayed in division and later give rise to an independent formation containing elements of all germ-layers, or that a fer-



tilized polar body (the fertilization of the polar body has been demonstrated in vertebrates) finds its way between the blastomeres of a developing ovum, and later develops within the embryo. The first assumption seems more probable, and the embryomata of the ovary may consequently be regarded as *rudimentary unioval twin malformations* (see §§ 128 and



FIG. 358.—Teratoma (adenomyosarcoma) of the testicle (formalin, hæmatoxylin, eosin). *a*, Cellular tissue with bands of muscle; *b*, gland-tubule.  $\times 100$ .

147), which are to be placed in the same category with the foetal inclusions of other organs. The fact that the ovaries (and testicles) form the favorite seats of such growths is probably dependent upon the fact that the urogenital anlage in its earliest stage forms relatively such a large part of the embryonal anlage (Bonnet), or that the blastomeres, from which the sexual glands later arise, more easily than others take on an especial development, which leads to the formation of a rudimentary twin.

The **teratomata of the testicle** occur most frequently in forms which according to their structure are designated as *adenocystoma*, *chondroadenoma*, *chondrosarcoma*, *adenomyosarcoma* (Fig. 357), *cystosarcoma*, *cystocarcinoma*, etc. In some cases the formation of cysts with fluid contents forms the most striking feature of the tumor (Fig. 315); in other cases cysts are found only in certain parts of the growth; and, finally, in still other cases the tumor may be solid throughout. These growths may reach the size of a child's head. They may be congenital, but develop more frequently in adult life, and then grow rapidly.

The lining of the cysts is, as a rule, of entodermal character, but may vary in one and the same cyst (Fig. 357). Simple cubical (Fig. 357, *b*) and cylindrical epithelium either with or without cilia, as well as stratified ciliated epithelium (*d*) and pigmented epithelium (*e*), may be found.

Ectodermal tissue is present only in scanty amount, and is limited to pigmented epithelium or to scattered groups of cells showing cornification; or it may be entirely absent, or, at all events, cannot be demon-

strated in the case of tumors of large size. Besides the cysts, mucous glands may also be found.

Of the connective-tissue substances, fibrous tissue, myxomatous tissue, cartilage (Fig. 357, *g, h*), and occasionally also muscle (Fig. 358, *a*), fat tissue, and more rarely bone, are present.

Teratomata of the character of **dermoids**, containing, as in the case of the ovarian dermoids, such structures as skin, brain tissue, cranial and tracheal tissues, and more rarely teeth and structures resembling the eyes, are of rare occurrence in the testicles, but are found both in children and in adults.

To what extent the different teratomata of the testicles are to be classed with the **embryomata**, or to what extent they can be explained by the assumption of tissue implantations at later stages of embryonal development, cannot at present be determined. When elements of all the germ-layers are present in the tumor, the assumption is justified that the growth belongs to the embryomata or embryoid tumors, and has arisen in the same manner as has been assumed in the case of the ovarian dermoids. The presence of single tissue-formations—as, for example, of cartilage or of muscle—in tumor-formations of a more simple character, may be explained by the assumption that such tissues find their way into the anlage of the testicle during the period of embryonal development.

Numerous hypotheses have been advanced concerning the **origin of the teratomata of the sexual glands**, particularly of the dermoids. Of the more recent investigations concerning this question, those of *Wilms* are in particular worthy of consideration. This author has carried out extensive researches into the structure of these growths, and has emphasized with great force that the fact that these tumors contain elements of all germ-layers necessitates the assumption of their development from an ovum. *Bonnet* has thrown light upon the question from the standpoint of the embryologist, and likewise emphasizes the view that the complex teratomata which contain elements of all germ-layers must arise from an ovum, but that portions alone of a ripe and fertilized ovum, as a fertilized polar body, may develop into such an embryoma. The attempt of *Bandler* to refer the embryomata of the germinal organs to ectodermal implantations occurring accidentally during the development of the urogenital system cannot be regarded as successful, inasmuch as the anlage of many formations contained in embryomata (teeth, thyroid, eye) cannot possibly be located in the region of the urogenital anlage.

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See also §§ 127 and 128.

## CHAPTER IX.

### Disturbances of Development and the Resulting Malformations.

#### I. General Considerations Regarding Disturbances of Development and the Origin of Malformations.

§ 130. After the copulation of the sexual nuclei has taken place, the development of the embryo proceeds by a progressive division of nuclei and cells, associated with which there arise in an orderly manner especial groupings of cell-complexes and differentiation of the same into especial tissues and organs. The multiplication of the cells, as well as the development of individual cell-groups into especial organs and parts of the body, depends upon intrinsic causes, and is controlled by the characteristics which the embryo has received through the transfer of the inheritable paternal or maternal characteristics at the moment of the union of the sexual nuclei, which are to be regarded as the carriers of inheritable characteristics. It follows, therefore, that the characteristics of the species as well as the especial peculiarities of the given individual are in general already predetermined in the germ, and the development of the embryo proceeds essentially under the control of innate moulding forces. Nevertheless, this development is not accomplished without the influence of environment, in that the embryo of necessity receives its nourishment from the maternal organism, and at the same time is exposed to mechanical influences on the part of its membranes and of the uterus. These influences may therefore operate to modify the development of the fœtus.

In every species of animal, man included, both the bodily form and the configuration of the organs present a *particular type*, which experience has shown constantly to recur, and which is therefore looked upon as normal. If more or less marked departures from this type occur, which can be referred to a more or less marked abnormal course of the intra-uterine development, the condition is designated as a **congenital malformation**. When the departure from the normal structure is very marked, so that the affected individual is grossly malformed, it is spoken of as a **monster**.

According to common usage, the term malformation is usually applied only to anomalies in the form of the body as a whole, or to single parts of it which present to external inspection rather striking departures from the normal. It is nevertheless entirely correct to use this term for pathological conditions of intrauterine origin, which consist not so much in an abnormal change in form, but rather in an incomplete or faulty organization of the affected part or organ.

A malformation affecting a single individual is known as a **single malformation** or **single monster**; one made up from two individuals is termed a **double malformation** or **double monster**.

*Malformations may owe their origin to either intrinsic or extrinsic causes.*



As **intrinsic causes** may be considered all such as already exist in the germ, so that in the development of the embryo malformations may arise spontaneously without the aid of extrinsic influences. When such a malformation occurs for the first time in a family, it must be regarded as a *primary germ-variation*. This may be explained in one of two ways: either one or both of the sexual nuclei entering into union may have been abnormal, or both may have been normal, but from their union a variety has arisen which from one point of view is to be regarded as pathological (cf. § 18). It is also possible that disturbances in the processes of fertilization can give rise to pathological variations.

If a similar malformation has already occurred in the parent, the case may be regarded as one of *inheritance*. If the malformation appearing is a peculiarity which was not present in the parents, but did show itself in more remote ancestors, while wanting in the intermediate links, the phenomenon is designated as *atarism*.

As primary germ-variations appear the same malformations which are also inheritable—that is, only those malformations are inheritable which originally appeared as primary germ-variations. To such inheritable malformations belong the increase in the number of

the fingers and toes (polydactylism), malformations of the hands and feet, abnormal hairiness, harelip, and certain pathological conditions of the nervous system, as, for example, multiple fibromata of the peripheral nerves.

Under **extrinsic causes** of malformations are to be considered especially *concussion, pressure, disturbances in the supply of oxygen and nourishment, and infections*.

Concussions of the uterus may in all probability directly damage the embryo at a very early stage. At a later stage of development the harmful effects of trauma are probably more often to be sought in a tearing loose of the egg and in decidual hæmorrhages, whereby the nourishment of the embryo is disturbed. It is evident that hæmorrhages from other causes, also changes in and contaminations of the maternal blood, as in infections, and, further, pathological conditions of the uterus itself,

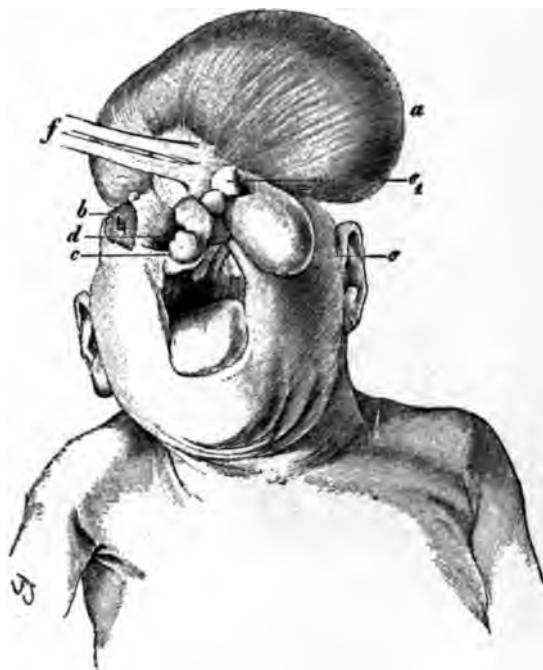


FIG. 350.—Malformation of the head, due to adhesions of the membranes to the frontal region (firm adherence of placenta to uterus). a, Membranous sac inclosing a vascular, spongy tissue containing numerous cysts; b, eye; c, lip; d, funnel-shaped depression lined with mucous membrane; e, left, e<sub>1</sub>, right ala nasi; f, connective-tissue bands. Reduced one-fourth.

may have a harmful influence upon the developing egg; yet all these conditions probably lead more often to the death of the foetus and the expulsion of the egg than to the development of a malformation. Infectious diseases of the mother may be transmitted to the foetus and give rise to their characteristic changes in the latter. An abnormal pressure

from the uterus or its membranes may be exerted upon the embryo, especially when there is a deficient amount of amniotic fluid; and malformations of the extremities (Fig. 362), in particular, not infrequently show evidences of pressure having been exerted.

From the anatomical findings in many malformations it appears that **pathological conditions of the amnion** may exert a damaging influence upon the embryo and give rise to different forms of malformations.

This may be brought about through *abnormal adhesions between the embryo and the amnion*, as well as by *pressure of the amnion upon the embryonal anlage*. Even at the birth of the child adhesions in the form of bands and threads (Figs. 359, *f*; 361) may not infrequently be demonstrated, and their connection with the malformed parts is

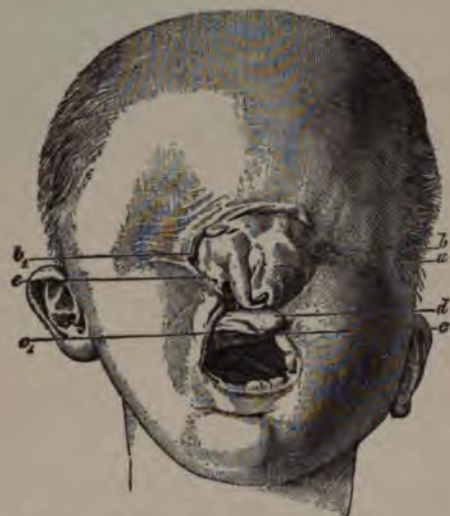


FIG. 360.—Malformation of the face, caused by amniotic adhesion and pressure. Asymmetry of the face. *a*, Malformed nose; *b*, *b*<sub>1</sub>, rudimentary lid-clefts; *c*, *c*<sub>1</sub>, clefts in the upper lip and alveolar process of the upper jaw; *d*, intermaxillary bone with prominent lip; *e*, oblique facial fissure closed by scar tissue so as to form a groove.

such as to leave no doubt that they stand in a causal relation to the malformation. Such adhesions may give rise to severe malformations of the cerebral (Fig. 359) or of the facial (Fig. 360) portions of the head. Not infrequently portions of the extremities are snared off by amniotic bands (Fig. 361), and may be completely amputated and then absorbed.

To what extent these adhesions of the amnion with the foetus are to be referred to primary adherence and intergrowth, and to what extent to inflammatory processes of later occurrence, is yet a disputed question. Not infrequently the adhesions at birth are no longer visible and the affected part presents only a scar-like appearance (Fig. 360).

According to Dareste and Geoffroy St.-Hilaire, an abnormal tightness of the amnion may easily exert a harmful influence upon the embryo. An abnormal closeness of the cephalic cap of the amnion may cause the malformations known as anencephalia, exencephalia, cyclopia, and cebocephalia or arrhinocephalia (§ 135); while an abnormal tightness of the caudal cap may give rise to sirenomelia (§ 139). Further, the cleft malformations of the anterior abdominal and thoracic walls (§ 137) are also associated with a faulty development of the amnion; still the latter condition is often not so much the cause as it is a concomitant of the malformation, which may be the result of a variety of causes, and, indeed, is often to be regarded as a spontaneous or primary malformation.



The period at which the injurious influence is active varies greatly, and consequently so does the extent of the damage done by it. The earlier the damage occurs, the greater the extent of the injury. Malformations in the narrower sense of the term arise chiefly during the first three months, during the period when the body and its individual parts are developing their proper forms. Damage to the fœtus at a later period occasions *changes which are more closely allied to those acquired after birth.*

Some malformations are **typical**—that is, they always appear in the same form; while others again are wholly **atypical**, so that the most astonishing anomalies of form may arise. The latter are for the greater part the result of extrinsic harmful influences operating secondarily, while the former may be regarded as owing their origin chiefly to intrinsic causes, although external influences may also cause typical malformations.

*Geoffroy St.-Hilaire* ("Hist. gén. et partic. des anomalies de l'organisation chez l'homme et les animaux," Paris, 1832-37) discards entirely the teaching of a primary abnormality of the germ (*Haller* and *Winslow*), and attributes arrests of development purely to mechanical influences. *Panum* ("Untersuch. über die Entstehung der Missbildungen," Berlin, 1860) agrees with him on the whole, although he admits the possibility of a primary abnormality. He produced malformations in hens' eggs by means of temperature variations and by varnishing the shells. *Darvett* ("Recherches sur la



FIG. 361.

FIG. 361.—Hand stunted by amniotic adhesions; ring-finger snared off; middle and index fingers grown together and distorted. Reduced one-sixth.



FIG. 362.

FIG. 362.—Hand stunted and deformed by pressure; thumb absent; hand flattened; great bending and shortening of the forearm. Reduced one-fifth.

production artificielle des monstruosités," Paris, 1877) made similar experiments and produced malformations due to arrested development by keeping the eggs in a vertical position, by varnishing the shells, by raising the temperature above 45° C., and also by irregular warming of the eggs.

Very recently *L. Gerlach*, *Fol*, *Warynsky*, *Richter*, *Roux*, and *Schultze* have in particular carried on experiments in this line, and have attempted, with partial success, to

produce malformations in chicken-embryos through the localized influence of radiant heat, variations of temperature, varnishing the eggs, changes of position, injuries, removal of a portion of the white of the egg, and by agitation. *Roux*, experimenting on frogs' eggs, found that, after destruction of one of the first segmentation-spheres, the other continued to develop and formed the half of an embryo, thus demonstrating that each of the first two segmentation-cells, corresponding in their position to the right and left body-halves, contains within itself the anlage material for the corresponding half of the body. But since the body-half which is wanting may later be replaced by subsequent development from the undestroyed half, and a whole structure be produced, each half must also possess the power of producing also the other half. According to investigations by *Hertitzka*, *Driesch*, *Morgan*, *Wilson*, and others, the first two or even the first four segmentation-cells in tritons, teleosts, ascidians, and echinoderms possess the power of forming an entire embryo.

*Schultze* experimented on the eggs of amphibia; these normally always assume such a position that the darkly pigmented protoplasmic substance of lighter specific gravity lies above, the heavier clear protoplasm rich in yolk granules lies below. By placing the eggs in an abnormal position and preventing their return to the normal position malformations may be produced, the degree of malformation standing in direct relation to the size of the angle formed by the line of gravity and the abnormally-placed axis of the egg. By turning the egg through an angle of 180° in the two-cell stage a double monster is regularly produced. The same turning in the eight-cell stage causes a complete cessation of development. These disturbances arise from displacements consequent upon the sinking of the heavier and a rising of the lighter constituents of the egg.

According to investigations by *O. Hertwig*, the eggs of axolotl, when kept in a 0.7-per-cent. solution of sodium chloride, undergo a pathological development, which is confined to the central nervous system in the region of the head and trunk. The sodium-chloride solution acts only upon those portions of the ectoderm which are in the process of changing into ganglion-cells; and as a result, with otherwise normal development, portions of the central nervous system may be lost.

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§ 131. **Single malformations** may be conveniently divided into five groups, according to the kind of change which characterizes them.

As **arrests of development** or **monsters due to defective development** (*monstra per defectum*) may be classed in the first place all those malformations in which the whole or a part of the body is abnormally small and imperfectly developed (*hypoplasia*), and also those malformations characterized by the complete absence or very great stunting (*agenesia* or *aplasia*) of individual organs or parts of the body. In this class belong, for example, the absence of the brain or of parts of it, or abnormal smallness of the brain, defects in the septa of the heart, defects and stunting of the extremities, etc.

If, in the case of parts or organs of the body which are normally formed by the union of anlage which are originally separated, such union should fail to take place as the result of a primary or secondary disturbance of growth, the arrest of development may show itself in the form of *clefts* and *reduplications*. Thus, for example, imperfect develop-

ment of the plates forming the anterior body-wall gives rise to clefts in the median line of the thorax and abdomen; a failure of union of the maxillary processes of the first branchial arch with each other or with the nasal process of the frontal bone gives rise to clefts in the face. Defective union of the bilateral portions of the female genital tract results in a more or less extensive reduplication of the uterus or vagina.

When the anlage of two organs lie near to each other, these may under certain conditions become united so as to produce a *coalescence* or *adhesion* between two organs or parts which should normally be separated. For example, the kidneys at times may be more or less united, and the eyes may be more or less completely merged into a single organ.

**Malformations due to excessive growth (*monstra per excessum*)** are characterized in part by *abnormal size* of individual parts, and in part by an *increase in number* of the same. For example, an extremity or a portion of one, as a finger, may reach an abnormal size (*partial giant growth*), or the whole body may be involved in the abnormal growth (*general giant growth*). An increase in number occurs particularly in the case of the mammary gland, spleen, adrenals, and fingers. Additional glandular organs are designated *accessory* or *supernumerary organs*.

**As malformations due to an abnormal disposition of organs (*monstra per fabricam alienam*)** are designated by Förster certain anomalies of the internal organs of the thorax and abdomen, which are characterized by an abnormal position of the organs, and in part also by changes in the relation of individual parts to each other. In this class belongs the condition known as *situs transversus*—that is, the transposition of the thoracic or abdominal organs, or of both. Further, various *defects in the heart and great vessels* may also be classed here, though it should be noted that these are more properly regarded as *arrests of development*.

A fourth group of malformations includes those characterized by **displacement of tissues** and by the **persistence of foetal formations**, as already mentioned in §§ 127 and 128.

Finally, as a fifth group may be classed those **malformations exhibiting a mixture of the sexual characteristics**, known as *true and false hermaphroditism*. True hermaphrodites possess both male and female sexual glands; false hermaphrodites are unisexual, but the remainder of the sexual apparatus does not correspond to the sexual gland, or there is a simultaneous formation of organs belonging to both the male and female. A part of these malformations are arrests of development; others are to be regarded as cases in which from the original bisexual anlage the organs of both sexes have developed, whereas normally the anlage of one sex undergo a retrograde change instead of developing, and persist only in a rudimentary form.

§ 132. **Double monsters (*monstra duplica*)** are malformations in which the entire body or a part of it is duplicated. The twins are always of the same sex, and are usually united at corresponding portions of the body. The duplicated parts are sometimes equally, sometimes unequally developed; in the latter case one of the parts is dwarfed and appears as a parasitic appendage to the well-developed individual or is inclosed within the body of the latter. We may accordingly distinguish **equal** and **unequal** forms of **double monsters**.

*All double monsters arise from a single egg and develop from a single germinal vesicle.* The **disturbance of development** may occur during the course of the segmentation process, but is first recognizable when from the germinal vesicle there is formed a double *embryonal anlage*. A

double monster may then arise either through the two embryonic areas being united from the very beginning, or that, originally separated, they infringe upon one another in their growth and blend to a greater or less extent. A second possibility is the formation within a single embryonic area of two primitive streaks and then two medullary grooves, which may remain entirely separate from each other or only partially blend. A third possibility would be a single primitive streak, but a medullary groove which is double either in part or in the whole of its extent. Finally, it is possible that under certain conditions a duplication takes place at a later period of development and then affects only individual parts of the axial zone or only the parietal zone.

The causes of a duplication of the embryonal anlage in a single germinal vesicle are not known. According to *Fol*, double and multiple monsters arise through the abnormal impregnation of an ovum with two, three, or more spermatozoa; but other observations (*Born*) indicate that ova fertilized by two or more spermatozoa do not develop. According to *Marchand*, the doubling of the anlage is to be referred to conditions existing before the beginning of segmentation, either to conditions within the egg before fertilization, or to the fertilization itself. *Wiedemann* and *Wetzel* hold the opinion that the origin of double monsters dates from the moment of impregnation, and is due to the fertilization of ova containing two germinal vesicles by two spermatozoa.

Successful experiments in the artificial production of double monsters from the eggs of animals have been made in recent years by *Gerlach*, *O. Schultze*, and *Born*. *Gerlach* produced double monsters (anterior duplication) from hens' eggs by varnishing these before incubating, leaving free only a Y-shaped spot in the region of the primitive streak. Inasmuch as he only rarely succeeded in obtaining such results, it is possible that these malformations, which not infrequently occur in chickens, were accidental. *Schultze* obtained double monsters by turning frogs' eggs during the two-cell stage through an angle of 180° (cf. § 180). *Spermann* was able to produce double-headed embryos of tritons by constriction of the embryonal anlage before the closure of the medullary plate to form the medullary groove. *Born* succeeded in uniting together portions of the larvæ of amphibia, not only of the same kind, but also of different species, genera, and families (*Rana esculenta* with *Bombinator igneus*, and with *Triton*). The conditions were most favorable for union in the case of larvæ of about 3 mm. length. Not only the external coverings of the body, but also the anlage of organs (liver, intestine, heart-tube), were blended into a united organ, the union being completed through specific tissue of the same kind. From all these experiments the conclusion may be drawn that double monsters may be produced from a normal egg through secondary influences, and that neighboring embryonal anlage may grow one into the other. On the other hand lies the possibility that especial conditions within the egg before fertilization may be the cause of the duplication. According to *Schultze*, this may possibly lie in the presence of two nuclei or of two spindles, or in an over-ripe condition of the egg with a tendency to fragmentation into two halves, which divide shortly before fertilization. Therefore a normally fertilized ovum in the two-cell stage may be brought through some influence (as in the experiment of *Schultze*) to the formation of two individuals.

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## II. The Different Forms of Malformations in Man.

### I. ARRESTS OF DEVELOPMENT IN A SINGLE INDIVIDUAL.

#### (a) Arrest of the Development of the Entire Embryonal Anlage.

§ 133. An arrest in the development of the entire embryonal Anlage manifests itself in two ways. If the disturbance is very marked,

a further development of the embryo is impossible, and it either dies at once or becomes stunted, and after a certain time perishes. If the disturbance is less severe there develops a normally formed foetus, but it remains small and stunted—that is, a dwarf is formed (*nanosomia* or *microsomia*).

A dead foetus is in the majority of cases expelled together with its membranes (*abortion*). In other cases in which the embryo for some cause or other remains stationary in development, the egg may remain for weeks or even months in the uterus and increase in size, so that



FIG. 363.—Portion of a hydatid mole. Natural size.

there arises a disproportion between the size of the embryo and of the egg. According to His, the first changes *after death* are shown in a marked swelling of the central nervous organs, leading to changes in the con-



figuration of the head. Later there occurs an infiltration of the tissues with wandering cells, the boundaries of the organs become indistinct, the entire **embryo** becomes cloudy and soft, the superficial structure



FIG. 364.—Lithopedion, entirely inclosed in connective-tissue membranes (removed from abdominal cavity by operation two years after beginning of pregnancy). Extrauterine pregnancy caused by embryo breaking through the uterine portion of a tube into the abdominal cavity. Reduced to one-third.

indistinct, and the embryo finally becomes **completely dissolved**. According to Berlet and Engel the wandering-cells infiltrating the tissue arise in the embryo itself, and indeed from its blood.

The **membranes** remaining in the uterus not infrequently suffer pathological changes before their expulsion. Most frequently they form the so-called **flesh-thrombus** or **blood-mole**—fleshy lumps consisting of the membranes and coagulated blood. The blood-clots form the chief part of their mass, and are often the cause of the death of the foetus. In the case of the **grape-** or **hydatid mole** (Fig. 363) the villi of the chorion or placenta suffer an extreme hydropic swelling, so that portions of the villi become changed into bladder-like structures which are held together by delicate connecting strands. The firmer portions of the connective tissue are pressed apart by fluid and ultimately undergo liquefaction, especially in the central portions. The epithelium of the villi shows in some places evidences of proliferation, in other places hydropic degeneration.

When a foetus well advanced in development dies and remains within

the maternal organism there may result the formation of a **lithopædion**. This occurs most frequently in the abnormal situation of the ovum known as extrauterine pregnancy, in which the embryo lies in the peritoneal cavity, in a tube, or in an ovary. If the fœtus dies at such an advanced stage of development that it cannot be absorbed, it may be carried within the maternal organism for years. Not infrequently its form is perfectly preserved (Fig. 364), and the whole fœtus becomes inclosed in a connective-tissue membrane. In other cases the fœtus, in the course of time, becomes converted into a partially fluid mass, which contains the osseous remains, as well as fat, cholesterin, and pigment, and is surrounded by a fibrous capsule. Lime-salts are usually deposited both in the newly formed membranes as well as in the portions of the fœtus remaining, and for this reason the fœtus is known as a "stone-child" or "petrified child."

According to the condition of the fœtus there may be distinguished three chief forms of lithopædion (Küchenmeister). In the first the mummified fœtus may be easily shelled out from the calcified membranes (*lithocelyphos*). In the second form the fœtus becomes adherent to the membranes at various points which become calcified, while the other portions become mummified (*lithocelyphopædion*). In the third form the fœtus is discharged, through the rupture of the membranes, into the peritoneal cavity, and later becomes encrusted with lime-salts (*lithopædion* in the narrower sense).

*The long retention of a ripe or even older fœtus within the uterus (missed labor) is rare, but may occur (1) in an accessory horn of the uterus, (2) in interstitial pregnancy, (3) after rupture of the uterus.*

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#### (b) Defective Closure of the Cerebrospinal Canal and the Accompanying Malformations of the Nervous System.

§ 134. **Defective closure of the vertebral canal** leads to the malformations known as **rachischisis** or **spina bifida**. If the defect in the vertebral column is open so that at the bottom of the cleft the bodies of the vertebræ covered by membrane are seen, the malformation is ordinarily termed *rachischisis*. When, at the site of the defect, there is seen a protruding sac, the malformation is usually designated *spina bifida*, or

more correctly *spina bifida cystica*; though to this formation the names *rachischisis cystica* or *hydrorachis cystica* may also be applied.

In **rachischisis totalis** (*holorachischisis*) (Fig. 365) the bodies of the vertebrae form a shallow groove opening posteriorly, and usually covered by a thin, transparent membrane; in rare cases rudiments of the spinal cord are still present in the form of whitish bands and lines. In this manner there occurs a **total** or **partial amyelia**. The defect involves principally the motor tracts and centres, as well as the columns of



FIG. 365.—Craniorachischisis with total absence of the brain and spinal cord. The skull is covered with ragged membranous masses, the open spinal furrow with a delicate membrane (pia mater). Kypho-lordotic curvature and shortening of the spinal column. Reduced one-sixth.

Clarke and the lateral cerebellar tract, while the spinal ganglia are developed (Manz, Leonowa, K. and G. Petré), and may send sensory fibres into the membranous masses of the spinal groove.

The delicate membrane which lines the furrow and covers the dura mater lying beneath it upon the bones is the ventral portion of the spinal pia mater. A part of the nerve-roots may have undergone development, arising either from rudiments of the spinal cord or from spinal ganglia.

**Partial rachischisis** (*merorachischisis*) involves usually the sacrolumbar or the upper cervical region, while the intervening portions of the vertebral column are only rarely the seat of malformations. The dorsal surfaces of the bodies of the vertebrae whose arches remain rudimentary are covered for the greater part by a mass of red velvety tissue, which lies upon a delicate membrane, though the amount of this tissue may be very small or may even be wholly wanting. To the outside of this tissue-layer, which is not everywhere equally abundant and which diminishes at the sides, there comes next a delicate, transparent, vascular membrane; and next, outside of this, a zone of epidermoidal tissue somewhat thinner than normal skin, and often covered with many hairs, separating the reddened central area from the normal skin.

The soft red tissue lying in the central area is the rudiment of the malformed spinal cord, and consists of an extremely vascular tissue containing more or less numerous portions of the spinal cord, as nerve-fibres, ganglion-cells, and glia-cells, and is designated the *area medullo-vascularia* (von Recklinghausen). It is sometimes a continuous tissue, at other times it is scattered in bands and patches, and forms only a delicate veil-like net. Both the cranial and the caudal extremities of this median area may end in a distinct furrow, designated respectively as the *cranial* and *caudal polar furrow* ("Polgrube," von Recklinghausen), to which the spinal cord is connected anteriorly and in lumbosacral rachischisis the filum terminale caudally. The membrane on which the area lies is the pia mater, which also continues into the red marginal zone above mentioned, which, being covered with epithelium, is designated as the *zona epitheloseosa* (von Recklinghausen). The prominent zone bordering this and covering the rudiments of the vertebral arches is formed of skin and is known as the *zona dermatica*.

On the ventral side of the pia mater forming the covering of the defect is a space which is bounded below by the dura mater and the external layer of the arachnoid, so that it is in reality the ventral portion of the subarachnoidal space.

**Spina bifida cystica** or **rachicele** (*rachischisis cystica*) occurs in three chief forms: *myelomeningocele*, *meningocele*, and *myelocystocele*. According to its site there may be further distinguished a cervical, dorsal, lumbar, lumbosacral, and a sacral spina bifida. In general, a spina bifida is characterized by the development of a fluctuating tumor, which is in most cases visible externally (Fig. 366) on the posterior aspect of the spinal column (*spina bifida posterior*); but instances also occur in which the sac projects anteriorly from the spinal canal (*spina bifida anterior*), and others in which it is too small to be visible externally (*spina bifida occulta*).

**Myelomeningocele** appears most frequently as a *spina bifida lumbosacralis*, and usually forms a tumor varying in size from that of a nut to that of an apple and increasing in size after birth, in the region of the lower lumbar and upper sacral vertebrae. It is covered either by smooth or scar-like skin, or may be devoid of skin on its summit and there covered by a reddish, mucosa-like tissue (*area medullovascularia*). The



FIG. 366.—Spina bifida sacralis. (After Forriep and Förster.) Girl of nineteen years, born with a tumor the size of a pigeon's egg over the upper sacral and lower lumbar regions, which enlarged from the sixth year on, while at the same time club-feet developed.

portion uncovered by skin may be drawn in, like a scar. In rare cases there may be no external tumor (*spina bifida occulta*), the site of the cleft being indicated only by a more marked growth of hair or by a depression.

On opening the sac, which is composed of the arachnoid (Fig. 367, *e*) and the pia (*f*, *f*<sub>1</sub>), while the dura (*g*) does not extend over the dorsal portion of the sac, it may be seen that the lower end of the spinal cord



(*b*,) is drawn outward, and that the cavity of the sac is crossed by nerve-roots (*i*, *i*,). Occasional nerve-roots (*h*) may also spring from the columns of the cord (*b*,) in its course through the sac.

According to these findings there is, therefore, an accumulation of fluid in the meninges, a *hydromeningocele* (*hydrorachis externa circumscripta*), which is combined with a prolapse of the spinal cord, a *myelocele*. At the site of the protrusion the vertebral arches are defective, and this defect may reach as far as the hiatus sacralis. Smaller defects may involve only one or two vertebrae.

*Dorsal* and *cervical meningoceles* are much more rare than the lumbosacral. The defect in the vertebral arch is usually confined to one or two vertebrae. The spinal cord is here involved in the meningocele in so far that portions of it are drawn outward in the form of a band or cone.

**Hydromeningocele spinalis** arises from a hernial protrusion of spinal arachnoid due to a localized collection of fluid in the subarachnoid space. It may occur in the first place at the upper end of the spinal column in the case of a cleft of the upper cervical vertebrae, at the same time with hernia of the brain in the occipital region. More frequently, however, it occurs in the sacral region, where the hernial protrusion takes place either through a defect in the vertebral arches



FIG. 367.—Myelomeningocele sacralis in sagittal section, a little to the left of the median line. (After von Recklinghausen.) *a*, skin; *b*, *b*<sub>1</sub>, spinal cord; *c*, area medullovasculosa; *d*, cranial, *d*<sub>1</sub>, caudal polar groove; *e*, arachnoid; *f*, pia, somewhat separated from the arachnoid; *f*<sub>1</sub>, portion of pia mater turned over; *g*, dura mater; *h*, recurrent roots of the fourth lumbar nerve; *i*, radix anterior; *i*<sub>1</sub>, radix posterior of the fifth lumbar nerve, running free through the arachnoid sac; *k*, sacral nerve-roots between the arachnoid and pia; *l*, filum terminale.

and bodies or through the hiatus sacralis, or between vertebral arches, or through intervertebral foramina. In the majority of cases the dura takes no part in the formation of the sac, but views differ upon this point, and by many writers (Hildebrand) a dural sac is described. Through a progressive accumulation of fluid the sac may attain a very large size. Small meningoceles may be concealed in the deep tissues.

According to the direction of the hernial protrusion there may be distinguished a *meningocele posterior* and a *meningocele anterior*, the latter taking place through a defect in the bodies of the vertebrae (*rachischisis anterior*).

**Myelocystocele** or **hydromyelocele** (*syringomyelocele*) takes its origin in a dilatation of the central canal of the spinal cord, as a result of which a larger or smaller portion of the cord with its connective-tissue envelopes becomes converted into a cystic tumor. The dura is usually wanting over that portion of the sac protruding from the vertebrae.

According to von Recklinghausen, the wall of these sacs is formed essentially of the inner spinal meninges, but is lined on the interior by a cylindrical epithelium, and has at some part of its inner surface an area medullovasculosa—usually on the ventral side, rarely on the dorsal. Corresponding to this condition the roots, in case they are still preserved, spring mostly from the ventral, rarely from the dorsal outer wall of the sac. The cavity itself is crossed neither by bands nor by nerves.

Myelocystoceles occur, in the majority of cases, in lateral clefts of the vertebral column. They show a tendency to be combined *with defects and asymmetries of the bodies of the vertebræ*, and thereby often with *shortenings of the trunk*, which at times affect only the dorsal region, at other times also the lumbar region. Very frequently there exists at the same time an exstrophy of the abdomen, bladder, and intestine.

Myelocystoceles are mostly covered only by the outer skin, but are sometimes concealed deep down in the soft parts. They may further be combined with a meningocele, so that a *myelocystomeningocele* arises.

In cases of rachischisis there sometimes occurs a **division of the spinal cord into two parts** (*diastematomyelia*), most often in the case of a total rachischisis, in which indeed the rudiments of the spinal cord are usually only indicated. In partial rachischisis such division is more rare, but the separated strands of spinal cord are better developed, and the fibrous and bony coverings may, at the beginning or end of the cleft, send dividing septa between them. Cases have occurred in which each cord-half possessed an H-shaped area of gray matter.

The *origin of rachischisis* is to be referred to agenesis and hypoplasia of the medullary folds, which should form the medullary groove of the vertebral arches. The agenesis of the spinal cord is also to be dated from the very earliest period. Whether it is a primary agenesis predetermined in the germ, or whether extrinsic injurious influences, perhaps toxic substances (Hertwig), pressure from without, or the inclosure of foetal membranes, may have secondarily checked development or have destroyed parts already formed, it is usually difficult to determine; but the symmetrical distribution of the arrested development speaks in favor of the former view.

In cases of *spina bifida* with hernial protrusion, the *local defects in the bony vertebral column and the defective development of the dura mater*, which is usually wanting at the site of the protrusion, are to be regarded as the primary condition. The growth of the sac may be explained as due to congestive and inflammatory transudation, and many times the residue of inflammatory changes, such as thickenings and membranous adhesions, may be demonstrated in the pia.

In the earliest embryonic period the medullary groove is formed by the development on both sides of the median line of wall-like elevations of the ectoderm which are designated as the medullary folds. Through the converging growth and union of the latter the medullary groove is closed and formed into the medullary canal. Thereupon the cell-masses (primitive vertebral plates) lying at the sides of the newly formed canal form an envelope about it, which gives rise in the first place to a membranous, non-articulated vertebral column. In this, at the beginning of the second month, there arise discrete cartilaginous areas from which, in the course of further development, the vertebral bodies and arches are formed, while between them the intervertebral discs and vertebral ligaments appear. The development of the cartilaginous vertebræ is not completed until the fourth month, and up to this time the dorsal covering of the medullary tube consists of the united portions of the membranous vertebral column. The cartilaginous constituents of the vertebræ are in the course of development replaced by bone.

According to *von Recklinghausen*, neither the persistence of a connection between the medullary canal and the epiblast nor an excessive stretching of the wall of the medullary groove through bending of the axis of the embryo can be held responsible for the origin of myelocystocele and myelocystomeningocele. According to his view, the former is a deficient growth in the long axis of the vertebral column, characterized anatomically by shortness of the column, absence of vertebræ or parts of vertebræ, separation of wedge-shaped bony pieces from the bodies of the vertebræ, and by unilateral defects in the arches. The neural canal, then, in the course of normal development, becomes too long for the vertebral canal, and in consequence becomes *curled* or

kinked, and there is a tendency to a partial protrusion of the medullary tube at the point of sharpest bending. *Marchand* believes that this hypothesis is not applicable to all cases, and *Arnold* is also of the opinion that the causal relations between arrests of development in the muscle-plates and vertebral anlage on the one hand, and those of the medullary canal on the other, are not constant, but that a variety of harmful influences may give rise to one or more of these anomalies.

According to *O. Hertwig*, the ordinary spina bifida is an arrest of development depending upon a partially prevented closure of the blastopore ("Urmundspalte").

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§ 135. Faulty development of the cranium and the associated disturbances of cerebral development lead to those malformations known as *cranioschisis*, *acrania*, *hemicrania*, *microcephalus*, *anencephalus*, *exencephalus*, *micrencephalus*, and *cephalocoele*.

*Acrania* and *hemicrania* or *cranioschisis* are the results of an agenesia or hypoplasia of the bony and membranous portions of the cranial



FIG. 368.—Anencephalia et acrania. Reduced one-half.



FIG. 369.—Cranioschisis with Exencephalia.

vault, which arise either as primary disturbances of development or as the result of harmful extrinsic influences upon the cerebral anlage.

In *acrania* both the bony portion and the skin of the cranial vault (Figs. 368, 370) are wholly wanting, the surface of the base of the skull

being covered only with a membranous vascular tissue.

If the defect in the cranial vault is associated with a similar defect in the vertebral arches, there is produced the condition known as *craniorachischisis* (Fig. 365), in which the spinal column is usually shortened and bent, the head in consequence being drawn sharply backward and the face turned upward. Through a



FIG. 370.—Partial agenesis of the bones of the cranium in anencephalia. *a*, Defect; *b*, squamous portion of the occipital bone; *c*, parietal bone; *d*, frontal bone. Reduced one-fifth.

marked bulging of the eyes with deficient development of the forehead, these malformations may resemble frogs (*frog factus*).

In *hemicrania* the flat bones of the cranial vault have undergone more



or less extensive development (Fig. 370, *b*, *c*, *d*) and form a cranial cavity, which is small, in that the flat bones of the vault are elevated but a short distance above the base of the skull. If the bones of the cranium which have undergone an imperfect development yet unite with one another as under normal conditions, there is produced a simple **microcephalus**, which may be present at birth or develop later, as the result of imperfect development of the skull.

Acrania and hemicrania are often associated with **total anencephalus**, the base of the skull being covered only with a membranous, vascular, spongy mass, which is usually composed of vascular connective tissue containing scattered hæmorrhages, and showing no trace of brain tissue or only undeveloped rudiments (*area cerebrovasculosa*).

In other cases the meninges contain, besides cystic cavities and gland-like remnants of the medullary plate, also more or less developed brain-



FIG. 371.—Hydrencephalocele occipitalis.



FIG. 372.—Encephalomeningocele nasofrontalis.

substance, which usually protrudes through the defect in the cranial vault, giving rise to **exencephalus** (Figs. 359, 369). The hernial masses are either inclosed only by a soft membrane corresponding to the inner meninges, or they may be covered also by external skin.

With microcephalus there is also **micrencephalus**—that is, an abnormal smallness of the brain. The development of the brain is also usually deficient, or certain portions may be lacking.

If the cranium is in general closed, but presents **partial defects**, portions of the cranial contents may protrude externally in the form of a hernial sac. Such a condition is known as **hernia cerebri** or **cephalocele** (Figs. 371, 372). Defects of ossification (Ackermann), as well as a local weakening of the membranous cranial envelope, are doubtless the primary cause, though adhesions of the meninges with the amnion may also be a cause (St.-Hilaire). The dura mater is wanting over the extracranial portion of the sac (Muscattello).

The size of the protruding sac varies greatly; it may be so small as to be found only after careful examination, or it may be so large as to approach the brain in volume. If only the arachnoid and pia protrude as the result of a collection of fluid in the subarachnoidal space, the hernia is designated a **meningocele**. If at the same time there is a protrusion of brain-substance, it is known as **meningoencephalocele**. A hernia of brain-substance and pia without a collection of fluid is an **encephalocele**; if the protruding brain-substance contains a portion of a ventricle filled with fluid, it is designated a **hydrencephalocele**.

Cerebral hernias occur chiefly in the occipital region (*hernia occipitalis*), close above the foramen magnum (Fig. 371), and at the root of

the nose (*hernia syncipitalis*). In the latter region it may at one time involve chiefly the frontal bone (*hernia nasofrontalis*, Fig. 372), at another time the ethmoid (*hernia nasoethmoidalis*) or the lachrymal bone (*hernia naso-orbitalis*). More rarely hernias occur on the sides of the skull (*hernia lateralis*) or at the base of the skull (*hernia basalis*). The latter may bulge toward the nasopharynx (*hernia spheno-pharyngea*), or into the orbit (*hernia spheno-orbitalis*), or into the fossa sphenomaxillaris (*hernia sphenomaxillaris*).



FIG. 373.—Synophthalmos or cyclopia.

In the case of a central hernia the brain may be either normal or more or less malformed. As a result of a marked stunting of development, particularly in the region of the foremost of the three cerebral vesicles, the cerebrum may remain single, while at the same time a deficient separation of the ocular vesicles takes place (*cyclencephalia* or *cyclocephalia* of St.-Hilaire). In severe grades of this form of disturbance of development only one eye may be formed, lying in the middle of the forehead, or two eyes united together may be found in one orbital cavity (Fig. 373), so that the malformation may be designated **cyclopia**, or **synophthalmus**, and as **arrhinencephalus** (Kundrat). The nose is also stunted (Fig. 373) and forms a proboscis-like cutaneous tag attached above the eye, and devoid of bony foundation (*ethmocephalia*).

When the eyes are separate, yet abnormally close together, the nose in general may be normal, though very small at the root (*cebocephalia*).

In the more severe grades of these malformations the ethmoid bone and nasal septum may be wanting, and the upper lip and palate may be cleft in the median line, on one or both sides (Kundrat). In the lighter grades the forehead is merely reduced in size and sharply pointed like a wedge.

In the severe forms of these malformations the cerebrum consists of a sac (Fig. 374, *f*, *i*), occupying more or less of the cranial cavity and filled with a clear fluid; at those points where the sac does not touch the cranial wall the inter-



FIG. 374.—Cranial cavity of a synophthalmus microstomus opened by a frontal section (seen from behind). *a*, Skin and subcutaneous tissue; *b*, cranium; *c*, dura mater; *d*, tentorium; *e*, arachnoid; *f*, posterior surface of the cerebrum, consisting of a thin-walled sac covered by pia mater; *g*, swollen edge of cerebral sac; *h*, subarachnoidal space behind the cerebral sac; *i*, cavity of the cerebral sac, communicating with the subarachnoidal space through the enlarged transverse fissure; *k*, section through the corpora quadrigemina; *l*, section through the cerebellum; *m*, atlas. Seven-tenths natural size.

vening space is filled by fluid distending the subarachnoid space (*h*). In the less marked forms only individual portions of the brain are undeveloped, those parts chiefly affected being the olfactory lobes and nerves, the corpus callosum, a part of the convolutions, etc. The optic thalami are often blended together. The chiasm and the optic tract may be absent or present. The corpora quadrigemina (*k*), pons, medulla oblongata, and cerebellum (*l*) are usually unaffected.

The spinal cord and brain arise from the medullary canal. In that portion that is to become the brain, the neural canal changes very early into three vesicles. The most anterior of these, the forebrain, throws out from its lateral portions the primary optic vesicles, while the middle portion grows forward and upward and divides into the *telencephalon* or *forebrain*, and the *diencephalon* (*thalamencephalon*) or *tweenbrain*. From the former are developed the cerebral hemispheres, corpora striata, corpus callosum, and the fornix. From the tweenbrain are formed the optic thalami and the floor of the third ventricle. The second vesicle or midbrain forms the corpora quadrigemina, while the third vesicle divides into the isthmus, metencephalon, and myelencephalon, from which there are developed the pons, cerebellum, and medulla oblongata.

The cerebral portion of the medullary canal becomes inclosed by the primitive vertebral plates of the head, which form the membranous primitive skull, the basal portions of which become cartilaginous in the second month of fetal life. In the third month the basal cartilage and the membranous vault begin to ossify.

According to *G. St.-Hilaire*, and *Pannum*, acrania and anencephalus are to be referred to an abnormal accumulation of fluid in the cerebral vesicles, a *hydrocephalus*, occurring before the fourth month. *Darveste* and *Perts* oppose this view, and point out that in acrania the base of the skull is usually bulged inward and not pressed outward. They therefore seek the cause of acrania in a pressure exerted upon the cranium from without (*Perts*), due to an abnormal tightness of the cephalic cap of the amnion, which retards the development of the cranium. *Lebedeff* seeks the cause of acrania in an abnormally sharp bending of the body of the embryo, which he thinks occurs when the cephalic end of the embryo grows abnormally in the longitudinal axis, or in case the cephalic covering lags behind in its development.

By the sharp bending the change of the medullary groove into the medullary canal is thought to be hindered, or the canal after its formation is destroyed. From this could be explained the later absence of the brain, as well as of the membranous and osseous cranial covering. The cystic formations in the membranes lying upon the base of the skull are, according to *Lebedeff*, formed from the folds of the medullary plate, which sink into the mesoderm and are then snared off.

*Hertwig* thinks it possible that chemical substances circulating in the blood or secreted from the wall of the uterus may destroy the anlage of the brain.

It is very probable that acrania does not always arise in the same way, and while in one case the influences brought forward by *Perts* and *Lebedeff*, or also adhesions with the fetal membranes, may hinder the development of the skull and brain, it is probable that in other cases the malformation must be regarded as a primary agenesis, the causes of which were already present in the germ.

According to *K.* and *A. Petré*, the spinal ganglia in anencephalus are always normally developed; on the other hand, the columns of *Clarke*, the lateral cerebellar tracts, and the bundles of *Gowers* are either wholly wanting or are imperfectly developed. Likewise the pyramidal tracts are wanting, while the anterior-horn ganglion-cells and the anterior roots are developed. *K.* and *A. Petré*, therefore, regard the malformation as a system-defect in which the neurones of the second order are not formed; and they incline to the view that the malformation is to be referred to an abnormal anlage of the germ.

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(c) *The Malformations of the Face and Neck.*

§ 136. The development of the face not infrequently suffers disturbances leading to more or less marked **facial malformations**, which may appear alone or in association with malformations of the cranium. If the frontal process and the maxillary processes of the first branchial arch remain in a rudimentary state or are destroyed to a marked extent by pathological processes, there persists at the site of the face an open sinus giving rise to the conditions known as **aprosopia** (*absence of the face*) and **schistoprosopia** (*cleft face*), which may also be associated with a defective development of the nose and eyes.

More frequent than these large defects are smaller clefts involving the lips, alveolar process of the upper jaw, the upper jaw itself, and the hard and soft palates (Fig. 375), which are designated as **cheilo-gnathopalatoschisis** or "**wolf's jaw**." This malformation gives rise to a communication between the mouth and the nasal cavity (Fig. 375). The hard palate is cleft in the part bordering upon the vomer; the soft palate in the median line. In the alveolar process of the upper jaw the cleft runs between the canine tooth and the outer incisor or between the outer and inner incisors. The malformation may be bilateral or unilateral, and is sometimes primary and inheritable, at other times acquired secondarily, in part as the result of amniotic adhesions (Fig. 359).

Not infrequently the cleft involves only special portions of the regions mentioned, as the upper lip (*harelip*, *labium leporinum*), or, what is rarer, only the hard or soft palate. The lightest grades of this form of cleft-malformation are represented by a *notch* or *cicatricial line in the lips*, or by a *bifurcation of the uvula*.

**Prosoposchisis** or **oblique facial cleft** (Fig. 360) is the designation applied to a cleft running obliquely from the mouth to an orbit. It is usually associated with malformations of the brain. According to Morian, three forms may be distinguished. The first is a cleft beginning in the upper lip as a harelip, passing into the nasal cavity, thence around the ala nasi toward the orbit, and may extend even beyond the latter. The second form likewise begins in the region of a harelip, but extends outward from the nose toward the orbit. The third form extends from the corner of the mouth, outward through the cheek toward the canthus of the eye, and divides the superior maxillary process exter-



nally to the canine tooth. A *transverse cleft of the cheek* also occurs, passing from the corner of the mouth toward the temporal region.

**Median facial clefts** (*nasal cleft*) run in the median line involving the nose, upper jaw, and also the lower jaw, and may extend as far down as the sternum. The tongue may also be cleft (Wölfler). Further, the defect may extend even to the frontal bone and brain.

All of the above-mentioned clefts may be confined to small portions of the regions mentioned, and moreover attain varying depths.

If the development of the inferior maxillary process of the first branchial arch is retarded, the inferior maxilla also is imperfectly developed or wholly wanting, and there arise those malformations known as **brachygnathia** or **agnathia** (Fig. 376). The lower portion of the face



FIG. 375.—Double chello-gnathopalatoschisis.  
(Wolf's jaw.)



FIG. 376.—Agnathia and synotia.  
(After Guardian.)

appears as if cut away; the ears are sometimes brought so close to each other as to touch (*synotia*). Usually the superior maxillary processes are also imperfectly developed; not infrequently the ear is malformed.

Abnormal largeness of the mouth (*macrostomia*), abnormal smallness (*microstomia*), closure (*atresia oris*), and duplication of the mouth (*distomia*) are all rare.

When the embryonic external branchial clefts or internal branchial pockets fail in part to close, there persist fistulæ opening either externally or internally, or closed cysts. The former condition is known as **fistula colli congenita**. The mouths of the external fistulæ are usually found at the side of the neck, more rarely nearer to the median line or in the median line; those of the internal fistulæ open into the pharynx, trachea, or larynx. Very often the remains of the branchial pockets form only diverticula of the last-named organs. The fistulæ are for the chief part covered with mucous epithelium, sometimes ciliated, arising therefore from the visceral branchial pockets, according to von Kostanecki and von Mielecki usually from the second. In rare cases there is found a complete branchial fistula with both external and internal openings.

The **branchial cysts** arising from the branchial pockets are some-

times covered with mucous epithelium (ciliated epithelium) and contain fluid; hence they are called *hydrocele colli congenita*. At other times they possess an epidermoidal covering and inclose epidermoidal cell-masses, and are therefore classed with the *atheromata* and *dermoid cysts*. Disturbances of development of the anterior end of the branchial arch (mesobranchial field) and in the region of the third branchial pocket (thymus-anlage) and branchial cleft may lead to the formation of *dermoids* in the *submental region*, in the *root of the tongue*, and in the *mediastinum*.

The face and neck are developed in part from a single anlage, and in part from paired anlage. The latter are represented in the branchial or visceral arches growing from the lateral portions of the base of the skull ventrally in the primitive throat-wall. The single anlage, designated the frontal process, is a prolongation downward of the base and vault of the cranium, and is, in fact, nothing more than the anterior end of the skull. Between the individual branchial arches there are at a certain period cleft-like depressions known as the branchial pockets.

The frontal process and the first branchial arch form the boundaries of the great primitive mouth-opening, which has a diamond shape. In the course of development the first branchial arch sends out two processes, the shorter of which applies itself to the under surface of the anterior portion of the head and forms the upper jaw, while from the longer one the lower jaw is developed. The frontal process, which forms the anterior boundary, gives rise to a broad prolongation of the forehead, and then pushes on two lateral processes which are known as the lateral nasal processes. By further differentiation of the central portion of the frontal process proper, the septum narium is formed, which by means of two spurs, the inner nasal processes, produces the borders of the external nasal opening and the nasal furrow. The lateral nasal processes are the lateral portions of the skull, and later develop within themselves the ethmoid labyrinth, the cartilaginous roof, and the sides of the anterior portion of the nares. At a certain stage they form with the superior maxillary process a furrow running from the nasal furrow to the eye, the lachrymal fissure.

In the beginning the mouth is simply a large sinus, but is soon separated into a lower and larger digestive and an upper and smaller respiratory portion. This separation is brought about by the development, from the superior maxillary processes of the first branchial arch, of the palatal plates, which from the eighth week on blend into each other and at the same time unite with the lower border of the nasal septum. The union of the anterior portions of the palatal plates takes place earlier than that of the posterior portions.

Through the union of the contiguous portions of the frontal and nasal processes with the superior maxillary processes the cheek is formed and a continuous superior maxillary border, from which are developed later the lip and the alveolar process of the upper jaw and intermaxillary bones, while the external portion of the nose develops from the frontal process. The intermaxillary bones are developed as independent bones, but unite very early with each other and with the upper jaw.

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(*d*) *Faulty Closure of the Abdominal and Thoracic Cavities, and the Accompanying Malformations.*

§ 137. **Arrests of development in the formation of the ventral body-wall** may take place at different points and exhibit different grades of severity. They occur most frequently in the region of the umbilicus, where the closure of the abdominal cavity takes place latest. In the case of imperfect development of the abdominal wall at this point, so that a more or less extensive area of the abdominal cavity is closed in only by the peritoneum and the sheath of the umbilical cord—that is, the amnion—which are pushed forward by the abdominal organs (Fig. 377), there is produced the condition known as **omphalocele**, or **hernia funiculi umbilicalis**, or **umbilical hernia**. The umbilical cord is attached either to the summit or at one side of the hernial sac, and is more or less shortened.

If the anterior abdominal walls either wholly or in part fail to unite, there arise those conditions which are designated **fissura abdominalis**, or **gastroschisis completa** and **thoracogastroschisis**. These are characterized by the undeveloped abdominal coverings not having been separated from the amnion, but passing into it. The greater part of the abdominal organs lies in a sac formed by the amnion and peritoneum

(eventration). The peritoneum, however, may also be wanting, likewise the umbilical cord, and the umbilical vessels may pursue their course to the placenta independently.

A cleft confined to the thorax is called **thoracoschisis**. Should the heart, covered only with pericardium or wholly free, protrude through an opening in the cardiac region, the condition is designated **ectopia cordis**.

When the failure to close is confined to the region of the sternum, the condition is designated **fissura sterni**. This defect may involve either the whole or a part of the sternum, at times affecting the bones, at other times only the skin.

The protrusion of the urinary bladder through a cleft in the abdominal wall is known as **ectopia vesicæ urinariæ**.

Clefts of the abdominal wall are not infrequently associated with clefts of the parts lying behind the wall, not only in the case of large clefts (total), but also in the case of smaller ones (partial). When a cleft of the lower portion of the abdominal wall is associated with a cleft of the urinary bladder, so that the posterior wall of the latter protrudes through the abdominal fissure (Fig. 378, e), the condition is known as **fissura**, or **exstrophia**, or **inversio vesicæ urinariæ**. Occasionally the pelvic girdle and the urethra are also cleft, the latter being represented by a groove open anteriorly (Fig. 378, e). The exstrophy is then said to be complicated by a **fissura genitalis** and **epispadias**.

When an abdominal fissure or an abdominal and vesical fissure is combined with a fissure of the intestines, there is produced a **fissura abdominalis intestinalis** or **vesicointestinalis**.

The intestinal fissure is situated in the cæcum or beginning of the colon, and the mucous membrane of the cleft intestine protrudes through the opening in the same manner as the posterior wall of the bladder, so that the condition is called **exstrophia** or **inversio intestini**.

If the omphalomesenteric duct does not undergo its normal involution, there remains at the lower end of the small intestine an appendix of intestine called **Meckel's diverticulum**, which arises perpendicularly from the outer margin of the

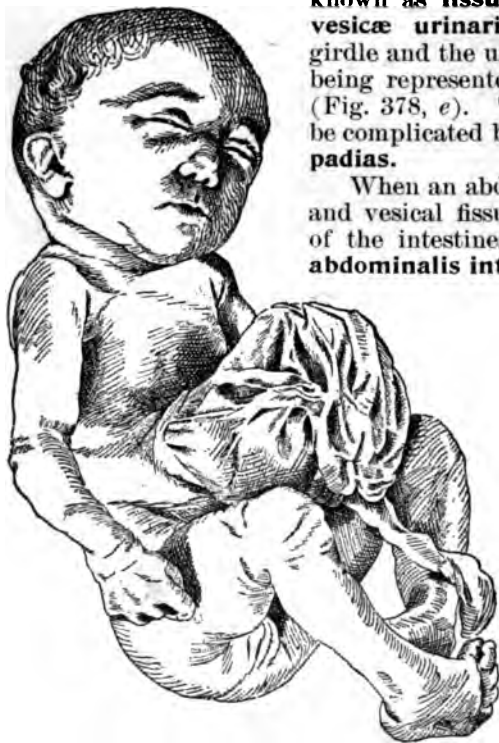


FIG. 377.—Hernia funiculi umbilicalis. Reduced to one-third.

intestine. It has usually the appearance of a glove-finger, and is either free at its end or attached to the umbilical ring, sometimes being dilated at its end. In the case of adhesion to the umbilical ring the intestinal mucosa may appear at the navel in the form of a tumor (**ectopia intestini**,



*adenoma umbilicale*). In very rare cases a cyst lined with mucous membrane may be formed in the abdominal wall (*omphalomesenteric cyst*).

Umbilical hernia and clefts of the upper portion of the abdominal wall are frequently combined with craniorachischisis, while exstrophy of the bladder and intestine is often associated with myelocystocele. Ac-

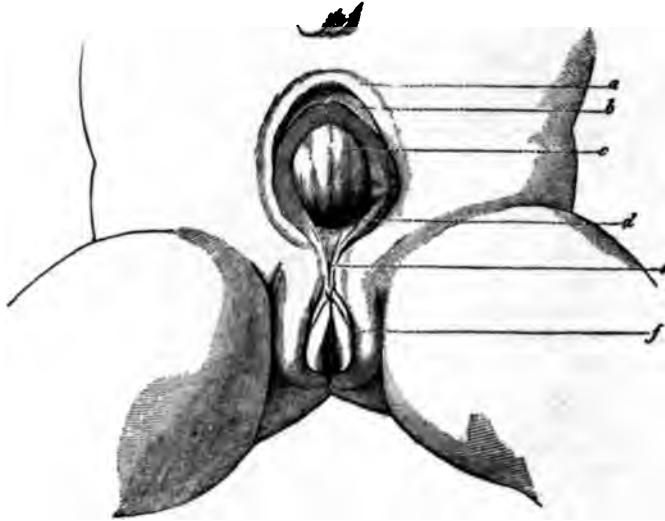


FIG. 378.—*Fissura abdominis et vesicæ urinariæ* in a girl eighteen days old. *a*, Border of the skin; *b*, peritoneum; *c*, bladder; *d*, small bladder-cavity corresponding to the trigonum; *e*, trough-like urethra; *f*, labia minora.

ording to von Recklinghausen, the two malformations are to be regarded as coördinated to each other. Further, large abdominal clefts are often associated with lordotic and scoliotic curvatures of the spinal column.

The development of the body-form from the flat embryonic anlage begins by a snaring-off of the individual germ-layers from the outer embryonal area, and their folding to form two tubes, the body-wall and the alimentary canal.

The infolding of these layers takes place at the cephalic and caudal ends, as well as at the lateral portions of the embryonal anlage, and as the summits of the folds gradually grow together from all directions, those which form the body-wall produce a tube whose cavity finally communicates only at the parietal umbilicus, by means of a peduncle-like prolongation, with the cavity of the extra-embryonic portion of the blastoderm known at this time as the vitelline membrane. While the lateral and ventral walls of the embryo are being thus formed, within the body the intestinal furrow also closes to form a tube, which is in communication at only one point lying within the parietal umbilicus, known as the visceral umbilicus, with the cavity of the umbilical vesicle, by means of a channel known as the omphalomesenteric duct.

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(c) *Malformations of the External Genitalia and Anus, due to Arrested Development.*

§ 138. Malformations of varying degree of the **external genitals** may be associated with malformations of the abdominal wall, bladder, and the internal genital organs, or may occur independently of these. **Complete absence of the external genitalia** occurs most frequently in connection with other malformations of this region, particularly in the case of sirenómelia, yet the region may in general present also a normal structure (Fig. 381). The internal genitals are usually also malformed.

A **stunted condition of the penis** is not rare, the organ in consequence coming to resemble more or less the clitoris. This condition is usually associated with a **hypospadias**—that is, the urethra opens on the under side of the organ, either beneath the glans, the body or the root of the penis (Fig. 379), or finally even behind the scrotum (*hypospadias perineoscrotalis*).

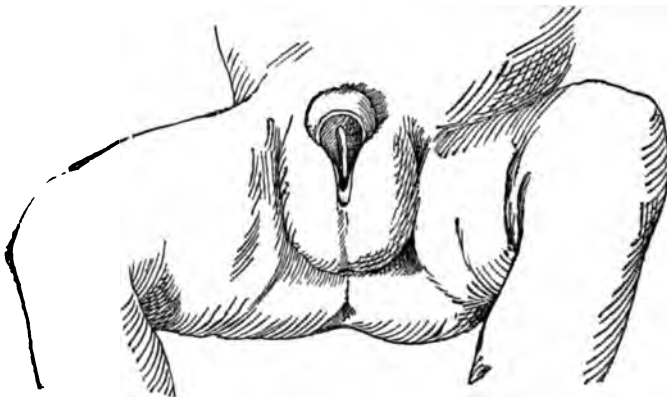


FIG. 379.—Hypospadias with stunting of the penis.  
Reduced one-fourth.



FIG. 380.—Epispadias.  
(After Ahlfeld.)

*spadias perineoscrotalis*). These malformations may exist in penises otherwise normally developed, and depend upon a partial failure of the sexual furrow to close.

**Epispadias** (Fig. 380) is that condition in which the urethral opening is found upon the dorsum of the penis. It is more rare than hypospadias, and is dependent upon a defective or delayed closure of the pelvis, so that the cloaca, before the closure, becomes divided into an intestinal (anal) and a genital opening (Thiersch). Under certain con-

ditions the penis remains cleft throughout its entire length; at the same time a fissure of the bladder and abdomen may be present.

**Hypertrophy of the prepuce** is not rare. If the preputial opening is narrowed so that the prepuce cannot be drawn back over the glans, the condition is designated a **hypertrophic phimosis**. **Total absence of the prepuce** is rare; an **abnormal shortness** is more frequent.

**Defective development of the scrotum** is usually associated with retention of the testicles in the abdominal cavity or in the inguinal canal, and leads to appearances whereby the external genital organs of the male come to resemble those of the female, especially so when the penis is also stunted.

In the female the **clitoris** as well as the **labia majora** and **minora** may show a **stunted development**. **Epispadias** and **hypospadias** occur also in the female sex, the former coincidently with a fissure of the abdominal and bladder walls (Fig. 378). In **hypospadias** a portion of the posterior wall of the urethra is lacking, and the urethral opening may be found at a greater or less distance within the vagina.

**Absence of the urethra** occurs in both sexes (Fig. 381). In girls the bladder may open directly into the vagina.

**Closure (atresia) of the urethra** occurs likewise in both sexes, and results either from a partial defect of the same or from obliteration of the orifice. An accumulation of urine in the bladder may lead to a marked dilatation of the same (Fig. 381).

An **abnormal narrowness of the urethra** may exist in a portion of its course or throughout its entire length. Further, its lumen may be narrowed as the result of a hypertrophic development of the *colliculus seminalis*.

In rare cases multiple orifices of the urethra have been observed. Further, in men there may be found in the glans penis a blind tube lying beside the urethra.

**Atresia ani simplex** is a closure of the anus, the intestine being at the same time well developed. It may arise from a failure of the ectoderm to fold in at the anal site, or a cloaca already existing and opening outward may again become closed through subsequent adhesions (Frank). If the rectum does not end immediately above the anal membrane but higher up, there exists in addition to the **atresia ani** also an **atresia recti**, a malformation which may occur even when the anus is well developed.

When, with absence of the anus, there is also an **arrested development** of the vaginal wall, which grows downward, between the *sinus urogenitalis* and intestine, to unite with the perineum, there remains a **cloaca**



FIG. 381.—Complete absence of the urethra and external genitalia, with extreme distention of the body due to an enormous dilatation of the bladder. Compression and stunting of the lower extremities. (In the posterior wall of the bladder rudiments of portions of the tubes and ovaries were found.)

in which the sinus urogenitalis and the end of the bowel unite. In other cases there are found **fistulous communications between the rectum and the bladder or urethra** (in boys) on the one hand, or between the **rectum and the vagina or uterus** on the other (*atresia ani vesicalis, urethralis, vaginalis, uterina*).

In rare cases the intestine, in the case of anal atresia, may open outward by means of **external fistulæ** in the perineum, scrotum, or sacrum.

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### (f) Malformations of the Extremities due to Arrested Development.

§ 139. **Defective development of the extremities** is not rare, and is to be referred in part to a primary defect of the anlage of an extremity, in part to a disturbance in the later development of the limbs or the bones, and in part to constrictions caused by strands of the foetal membranes or by loops of the umbilical cord. Further, such defective development of the extremities may also follow malformations of the central nervous system. According to the degree of malformation, the following different forms may be distinguished:

(1) *Amelus*. The extremities are completely absent; in their place are found only warty or stump-like rudiments. The trunk is usually well formed (Fig. 382).

(2) *Peromelus*. Stunting of all the extremities.

(3) *Phocomelus*. The hands and feet are alone developed and are attached directly to the shoulder and pelvis respectively.

(4) *Micromelus* (*microbrachius, micropus*). The extremities are developed, but are abnormally small (Fig. 383).

(5) *Abrachius* and *Apus*. Absence of upper extremities with well-developed lower ones, or *vice versa*.

(6) *Perobrachius* and *Peropus*. Stunting of the upper or lower extremities.

(7) *Monobrachius* or *Monopus*. Absence of one of the upper or lower extremities.



(8) *Sympus*, *Sirenornelia*, *Symmelia*. The lower extremities are fused together (Figs. 384, 385), and at the same time turned upon their axes so that their external aspects are in contact. The pelvis is usually



FIG. 382.—Amelus.



FIG. 383.—Micromelus with cretin-like facies.



FIG. 384.—Sympus apus.



FIG. 385.—Sympus dipus.

defective, as are also the external genitalia, the bladder, urethra, and the anus. At the end of the blended extremities feet may be entirely

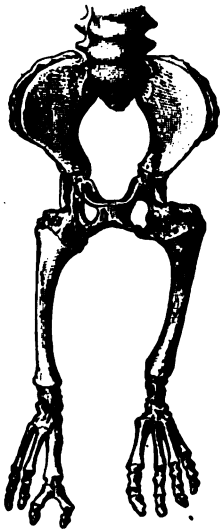


FIG. 386.



FIG. 387.



FIG. 388.

FIG. 386.—Absence of femur and fibula. Diminution in the number of phalanges. One-half natural size.

FIG. 387.—Perodactylism with syndactylism. Left hand of a new-born child. Seven-eighths natural size.

FIG. 388.—Skiagraph of same hand as in Fig. 387. Seven-eighths natural size.

wanting (*sympus apus*) and only a few toes may be present (Fig. 384); in other cases (Fig. 385) one (*sympus monopus*) or both feet may be present (*sympus dipus*).



FIG. 389.

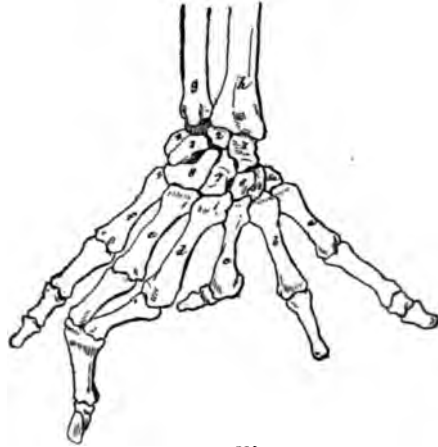


FIG. 390.

FIG. 389.—Malformation of the right hand, perochirus, with blending of the fingers. (After Otto.) *a*, Supernumerary thumb; *b*, thumb proper; *c*, stunted index finger; *d*, middle finger; *e*, ring finger; *f*, little finger.

FIG. 390.—Skeleton of the hand (perochirus) shown in Fig. 389, seen from the dorsal side. (After Otto.) *a-f*, as in Fig. 389; *g*, ulna; *h*, radius; *i*, os naviculare; *s*, os lunatum; *3*, os triangulare; *4*, os pisiforme; *5a*, os multangulum majus superfluum; *5b*, os multangulum ordinarium; *6*, os multangulum minus; *7*, os capitatum; *8*, os hamatum.

(9) *Absence of individual bones* may occur in any part of the extremities (Fig. 388).

(10) *Perodactylism*—*stunting of the fingers or toes*—appears in a great variety of forms, but in general is seen as a defective development (*brachyphalangism*) or complete absence of individual phalanges (Figs. 386, 388, 390, c), or as membranous (Figs. 387, 389) or bony (Figs. 388, 390, d, e) connections between the fingers (*syndactylism*).

If only the outer fingers or toes are developed while the middle ones are lacking, there arise those formations (Figs. 391, 392) designated as *cleft-hand* and *cleft-foot* (Kümmel). In more extensive malformations



FIG. 391.



FIG. 392.

FIG. 391.—Peropus or cleft-foot. (After Otto.) Right foot. a, Great toe; b, little toe.

FIG. 392.—Skeleton of the foot in Fig. 391, seen from the dorsal side. a, Great toe; b, little toe; c, rudiment of third toe; d, tibia; e, fibula; f, talus; g, calcaneus; 1, os naviculare; 2, os cuneiforme majus; 3, os cuneiforme minus; 4, os cuneiforme tertium; 5, os cubiforme.

of the fingers there occur in part also malformations and defects in the region of the tarsal and metatarsal bones (Fig. 392) or carpal and metacarpal bones respectively. These malformations are designated respectively as *peropus* and *perochirus*. Absence of the hand or foot is known as *achirus* or *apus*.

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## 2. ABNORMAL POSITION OF THE INTERNAL ORGANS AND OF THE EXTREMITIES.

§ 140. Of the abnormal positions of the internal organs, the most important is the one known as **situs inversus viscerum**—i.e., a *lateral transposition of the internal organs*, so that the position of the thoracic and abdominal organs forms a mirror-image of the normal position. This condition has been observed both in double monsters and in single individuals. It may be restricted to the heart alone, or to the abdominal organs, or more rarely to a part of the latter (*situs irregularis*), but the last is rare. In general, abnormal positions occur especially in the case of the abdominal organs. For example, the kidney is not infrequently found in an abnormal position (*dystopia renis*), usually abnormally low, so that it approaches the sacral promontory or lies in front of the same. The testis is not rarely retained within the abdominal cavity (*ectopia interna*, or *abdominalis testis*, or *cryptorchismus*), or within the inguinal canal (*ectopia inguinalis*), or at the external ring (*ectopia publica*), or in the fold between the thigh and scrotum (*ectopia cruroscrotalis*), or in the perineal region (*ectopia perinealis*), or in the fold of the groin (*ectopia cruralis*). Abnormal positions of the intestines, particularly of the colon, are not rare.



Among the abnormal positions of the extremities **congenital luxations** (slipping of the articular heads from their sockets) are of especial interest. They are most common at the hip-joint, more rare at the elbow-, shoulder- and knee-joints. According to von Ammon, Grawitz, Krönlein, and Holtzmann, the congenital luxations are in part due to *local arrests of development*, but may also be the result of mechanical influences. In the case of the hip-joint the disturbance of development results in a small and imperfect acetabular socket, and the head of the femur is usually more or less imperfectly developed. The small acetabulum lies in the normal position, but the head of the femur is displaced, most often backward (*luxatio iliaca*). At birth the ligamentum teres is always intact, and the capsule of the joint covers both the head of the femur and the acetabulum. After much use of the leg the ligamentum teres becomes stretched and may tear, the capsule becomes dilated and bag-like, and at the point where it is pressed against the bone may become perforated. A new joint may then be formed through the proliferation of the surrounding tissues.

**Abnormal positions of the feet and hands** are to be referred partly to disturbances of development and partly to mechanical influences exerted upon the extremities during their growth. The most important is **congenital club-foot** (*pes equinovarus*), which, according to Eschricht, is to be referred to an arrest of development, by which the foot is left in the foetal position, with accompanying abnormal development of the bones and their articular surfaces. The inner border of the foot is sharply elevated, and the foot at the same time brought into plantar flexion. The collum tali is elongated in an anterior and inferior direction (Hüter, Adams). If the children thus afflicted learn to walk, they tread upon the outer side of the foot, which thereby becomes flattened, while the foot becomes still more sharply turned inward.

Congenital club-foot, though usually to be regarded as a primary disturbance of development of the affected joint, may also under certain conditions be caused by an *abnormal pressure* due to a relatively small uterus (Volkmann). Under these conditions develop also those pathological positions of the foot known as *pes calcaneus* and *pes valgus*, which are characterized partly by strong dorsal flexion and partly by an outward twisting of the foot. Frequently the evidences of the pressure to which the feet have been subjected are seen in an atrophic condition of the skin and portions of the bones.

The position of the hand known as **clubbed-hand** or **talipomanus** is caused by a rudimentary development of the radius, and is usually associated with other malformations.

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### 3. MALFORMATIONS DUE TO EXCESSIVE GROWTH OR MULTIPLICATIONS OF ORGANS OR BODY-PARTS.

§ 141. The malformation known as **general giant growth** occurs as the result of an excessive growth of the entire body, either during intra-uterine life or later. During extra-uterine life such an abnormal growth may occur that the size of the affected individual may far exceed the maximum normal limits.

**Partial giant growth** may also take place during intra-uterine life or after birth. The head and portions of the extremities are usually affected. A *unilateral giant growth* is usually restricted to the half of the face or to one extremity, but in very rare cases the hypertrophy may involve all the parts of one side: face, trunk, and extremities. In extra-uterine life trauma sometimes gives the impulse to a pathological excess of growth.

In the pathological hypertrophy of an extremity, or of a portion of the same, as a finger, the structure of the part may in general preserve its normal relations, in that all the constituent tissues participate in the increased growth. In other cases the tissues are not equally involved, so that, for example, the soft parts, particularly the fat tissue, may become especially increased in amount. Further, the enlarged soft parts of the extremities often show a pathological structure, containing, for example, abnormally developed blood- and lymph-vessels. When the extremities are disfigured as the result of such an increase of tissue, the condition is usually called **elephantiasis**. If the thickened areas are sharply circumscribed, the formations are regarded as **tumors**, and, according to their structure, are classed with the angiomata, lymphangiomata, and fibromata (see §§ 103, 108, 109). On the trunk the local excesses of tissue-growth occur most frequently in the form of elephantiasis-like formations, or as tumors. The same is true of such growths of the soft parts of the face; the lips, cheeks, and tongue not infrequently being more or less enlarged and disfigured through the formation of connective-tissue hyperplasias richly supplied with lymphatic vessels.

Circumscribed hypertrophies of the bones occur in various portions

of the skeleton, and are sometimes multiple. The bones of the skull as well as those of the face may be thus affected, and there occur cases in which the hypertrophy of the bone may be so extensive that one or both of these regions may show marked disfiguration, and there are produced conditions which are known under the general term of *leontiasis ossea* (Fig. 126). Circumscribed hypertrophies of the bones lead to the formation of *osteomata* or *exostoses*, which are often multiple. On the trunk and extremities local growths of bone may lead to the enlargement of single bones as well as to the formation of atypical excrescences known as *osteomata* and *exostoses*, which are not infrequently multiple.

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§ 142. The occurrence of supernumerary organs, or of a multiplication of parts of the skeleton, and of the muscular system, is relatively frequent. Such phenomena are to be attributed in part to a cleavage or multiple appearance of the given anlage, and in part to a more marked development or persistence of organs which normally remain in a rudimentary state, or undergo retrogression during the period of growth. Further, certain of the conditions included under this head may be regarded as *reversions*.

1. **Duplications of the extremities.** A duplication of an entire extremity without the duplication of the pelvic or shoulder bones has not been observed in man. Duplication of the hands and feet is very rare (Fig. 393), but a number of cases are reported in the literature. The number of fingers may reach nine or ten.

Much more frequent is a **multiplication of the fingers (polydactylism)** on a single hand (or foot respectively), in which condition the supernumerary fingers (or toes) are attached in part at the ulnar or radial side (or tibial and fibular sides respectively), or in part intercalated between the others (Figs. 390, *a*; 394). Often the fingers are duplicated only in part—that is, by the cleavage of the first or the first and second terminal joints (Figs. 395, 396). Those attached at the margin of the hand may be well developed (Fig. 394) or rudimentary. Occasionally they appear as small pedunculated fibrous tumors. In the fully developed supernumerary fingers or toes the phalanges (Fig. 394) may articulate with the metacarpal or metatarsal bones of a neighboring finger or toe, or with

their own (supernumerary) carpal or tarsal bones (Fig. 390, 5a). Polydactylism in certain cases is inherited and is therefore dependent upon intrinsic causes. A duplication of a finger may also occur through cleavage of the anlage under the influence of intra-uterine influences, and is consequently not inheritable.



FIG. 393.

FIG. 393.—Polydactylism with forking of the hand. (After Lancereaux.)



FIG. 394.

FIG. 394.—Polydactylism in a new-born child. Skeleton. Duplication of the phalanges of the fourth and fifth fingers. Natural size.



FIG. 395.

FIG. 395.—Polydactylism and syndactylism of the left hand. Reduced one-fifth.



FIG. 396.

FIG. 396.—Polydactylism and syndactylism of the right foot. Reduced one-fifth.



2. **Supernumerary nipples and breasts (hyperthelia, hypermastia)** are not uncommon malformations in both sexes, and are probably to be regarded as a reversion to polymastic racial ancestors. The supernumerary organs are usually situated on the thorax, along two lines converging from the axillary to the inguinal regions, but in rare cases they may be found elsewhere—in the axilla, on the shoulder, on the abdomen, back or thigh. They are usually small, but in the event of pregnancy may take on functional activity. The number of the nipples may reach as high as ten.

3. The **formation in men of breasts** resembling those of women (**gynæcomastia**) is rarely seen in well-developed men with normal sexual apparatus (see Hermaphroditism, § 143), but it not infrequently happens that the male breast undergoes a moderate enlargement at the time of puberty.

4. **Duplication of the penis** is of very rare occurrence, and may be associated with the formation of two urethræ having independent openings into the bladder, and with two scrota, the two penises being typically developed (Lange).

5. **Supernumerary bones and muscles** are of frequent occurrence. *Supernumerary vertebræ* may be found in any part of the spinal column; and at its lower end may in rare cases cause a lengthening of the column, resulting in the formation of a **tail**. According to Virchow, three forms of tails may be distinguished: true tails containing bones; false or imperfect tails which represent an elongation of the vertebral column, but contain neither cartilage nor bones (so-called pig's-tail); and tail-like appendages of skin which consist of different forms of tissue, and in part are to be classed with the teratomata. The true tails are very rare; according to Bartels, they are more often the result of a separation or elongation of the vertebræ than of an increase in their number.

*Supernumerary ribs* in the neck or lumbar region, as well as a forking of the ribs, are not rare.

*Supernumerary teeth* also occur.

6. **Duplication or cleavage of the anlage** of the **thoracic and abdominal organs** occurs most frequently in the case of the spleen, pancreas, adrenals, ureters, pelvis of the kidneys, and lungs, more rarely in case of the ovary, liver, kidney, testicle, and bladder.

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#### 4. TRUE AND FALSE HERMAPHRODISM.

§ 143. The fact that the sexual organs, both the sexual glands and the external genitals, of both sexes, develop from originally similar anlage which contain the beginnings of all the sexual organs of both sexes, makes it *a priori* probable that malformations might result through unequal development of the anlage of the right and left sides, or through a simultaneous development of organs peculiar to both sexes, or finally through a lack of harmonious development of the external and internal genitals.

Those malformations which are to be referred to some one of the factors named, and which are characterized by the fact that the sexual apparatus of a single individual contains parts belonging to both the male and female, are grouped under the designation **hermaphrodisismus** (Fig. 397). When both sexual glands (testis and ovary) are present the condition is called **hermaphrodisismus verus** (*hermaphrodisismus glandularis*, Siegenbeek van Heukelom). If the mixing of sexual characteristics consists merely of a combination of male and female genital passages with the external genitalia of the opposite sex, the condition is known as **pseudohermaphrodisismus**. The true sex is determined by the nature of the sexual glands.

The body build of hermaphrodites frequently shows a curious mixture of male and female characteristics. For example, the breasts, neck, and shoulders may correspond to the female type, while the development of the beard, face, larynx, and voice may correspond to the male type. In false hermaphrodites the body characteristics do not always correspond to the true nature of the sexual glands; a male may resemble a female, and *vice versa*.

The following chief types of hermaphrodisism may be distinguished:

1. *Hermaphrodisismus verus* or *androgynes*.—1. *Hermaphrodisismus verus bilateralis*, or double-sided hermaphrodisism, is characterized by the presence on both sides of both ovary and testis, or the presence on both sides of an organ containing both ovarian and testicular tissue. Heppner asserts that in a nine months' old child, having hermaphroditic external genitals, with vagina, uterus, and tubes, both ovary and testis were found in the broad ligament; epididymis and vas deferens were wanting.

2. *Hermaphrodisismus verus unilateralis*, or one-sided hermaphrodisism, is that condition in which upon one side there exists but one sexual gland, while on the other both testis and ovary are present. Salén has reported a case of a woman of forty-three years of age, who had menstruated since her seventeenth year, in whom there was found upon the right side (castration on account of uterine myoma) a hermaphroditic gland, the

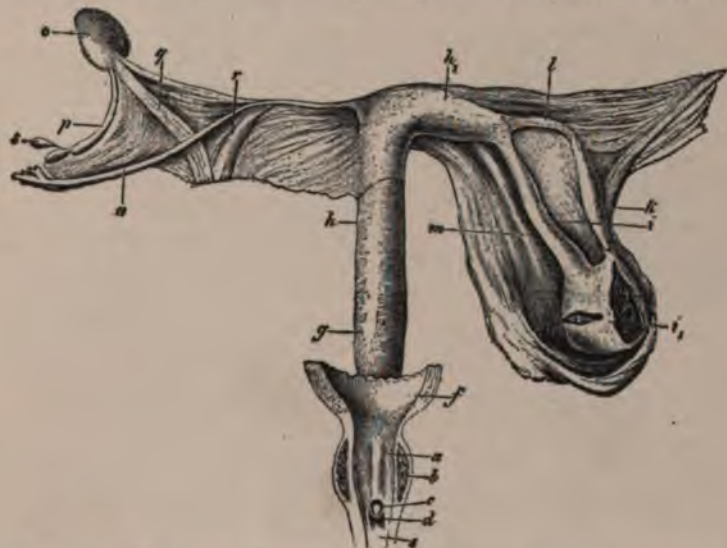


FIG. 397.—*Hermaphrodisismus verus lateralis*. (After Obolonsky.) a, Urethra; b, prostate; c, colliculus seminalis; d, hymen; e, canalis urogenitalis; f, bladder; g, vagina; h, uterus; h<sub>1</sub>, left uterine horn; i, left tube; i<sub>1</sub>, infundibulum of left tube; k, left ovary; l, ligamentum ovarii; m, ligamentum teres sinistrum; n, right tube; o, right testicle; p, epididymis; q, right vas deferens; r, ligamentum teres dextrum. About one-half natural size. (Specimen in the collection of the Pathological Institute of the German University in Prague.)

nature of which was confirmed by accurate microscopical examination. The ovarian portion of the gland was typically developed; the epithelium of the seminiferous tubules of the testicular portion consisted of follicular cells and cells of Sertoli, but lacked spermatogonia and seminal cells. Blacker and Lawrence have also described a case of hermaphroditic gland occurring in a child still-born at eight and a half months.

3. *Hermaphrodisismus verus lateralis* is that condition in which there is an ovary on one side and a testis on the other. It has been many times observed in man (Rudolph, Stark, Berthold, Barkow, H. Meyers, Klebs, Messner, and others), though in the majority of cases no careful microscopical examination was made, and when carried out, ovarian tissue could not with certainty be demonstrated. Several years ago Obolonsky reported a case (a twelve-year-old girl) from the collection of the German

University in Prague, in which the histological examination showed on the right side a testicle (Fig. 397, *o*), and on the left side an ovary (*k*), but it is to be noted that ova were not seen in the latter. The right broad ligament contained a testis (*o*), an epididymis (*p*), a vas deferens (*q*), a rudimentary tube (*u*), a round ligament (*r*); the left broad ligament, on the other hand, contained an ovary (*k*), with an ovarian ligament (*l*), and a well-developed tube (*i*). Moreover, a uterus (*h*), vagina (*g*), and also a prostate (*b*) were present. According to the reported observations, the corresponding sexual passages may be wholly or in part wanting. The external genitals are malformed, and combine structures belonging to both sexes.

II. **Hermaphrodisismus spurius**, or **pseudohermaphrodisismus**, is characterized by a bisexual development of the sexual passages and external sexual organs in association with a unisexual development of the essential sexual gland. The most pronounced cases occur in males,

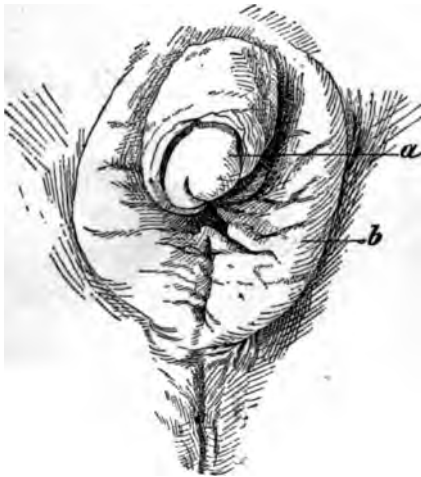


FIG. 398.—External genitals of a female false hermaphrodite, with stenosis of the vaginal orifice. *a*, Penis-like clitoris; *b*, labia majora.

who, in addition to their proper sexual organs, possess a more or less well-developed vagina, uterus, and tubes. It is much more rare to find in females a development of a portion of the Wolffian duct.

In male false hermaphrodites the external genitals are frequently malformed and approach the female type, while in female false hermaphrodites the external genitals resemble those of the male (Fig. 398).

The resemblance of the male external genitals to those of the female is brought about by a stunting of the penis and a total or partial failure of the sexual furrow in the penis to close (hypospadias), so that the two halves of

the scrotum are separated, leaving a depression beneath the root of the penis, which represents the remains of the sinus urogenitalis. The scrotal halves come, therefore, to resemble the labia majora, particularly in the case of non-descent of the testicles. The external genitals of the female approach in appearance those of the male through the development of the clitoris into a sort of penis (Fig. 398, *a*), while the vaginal opening is narrowed or closed through the union of the labia. The vagina and urethra have a common opening, or open separately beneath the penis-like clitoris.

The atypical development of the external genitals may or may not be associated with malformations of the sexual passages; and is, therefore, not dependent upon malformations in other portions of the sexual apparatus.

1. *Pseudohermaphrodisismus masculinus* occurs in three varieties:

First, *pseudohermaphrodisismus masculinus internus*, in which condition the external genitals are of the male type, and the prostate is developed, but is usually pierced at the colliculus seminalis by a canal opening into



the urethra, the former being continued above into a rudimentary or more or less well-developed vagina, often also into a more or less well-formed uterus, and even tubes. The male organs may be well developed or more or less malformed.

Second, *pseudohermaphrodisismus masculinus completus*, or *externus et internus*, in which form the vagina, uterus, and tubes are present in a state of rudimentary or more or less complete development, while the external genitals resemble more or less completely the female type. The penis presents the condition of hypospadias and resembles the clitoris; beneath it lies a furrow at whose posterior end there is usually an orifice leading into a short vestibule which divides at once into a urethra and a vagina. Sometimes the vagina and vestibule are separate. In rare cases the external genitals appear normal, but the penis contains a double canal, the upper one representing the urethra, the other the sexual passage. In the case of a more marked development of the ducts of Müller the vasa deferentia are frequently defective, and the seminal vesicles are sometimes wanting.

Third, *pseudohermaphrodisismus masculinus externus*, in which only the external genitals depart from the male type, and resemble more or less closely the female. As in these cases the bodily habitus often simulates that of the female, the true sex of the individual may easily be mistaken.

2. *Pseudohermaphrodisismus femininus* also occurs in three similar varieties, but is of much rarer occurrence.

In *pseudohermaphrodisismus femininus internus* rudiments of the Wolffian ducts, lying in the broad ligament or in the uterovaginal wall, and sometimes extending to the clitoris, are found in association with well-developed external genitals.

*Pseudohermaphrodisismus femininus externus* is characterized by external genitalia resembling those of the male (Fig. 398).

*Pseudohermaphrodisismus femininus externus et internus*, in which the external genitals resemble those of the male and there is a persistence of parts of the Wolffian ducts, is very rare. Of the internal male genitalia, there was found in one case a prostate, and in another case a prostate pierced by the vagina, an ejaculatory duct, and a sac resembling a seminal vesicle, which opened into the vagina.

The **internal sexual organs** develop from the same undifferentiated anlage in both males and females. These anlage consist of a sexual gland lying on the medial anterior side of the *Wolffian body*, and a *sexual passage* known as the *duct of Müller*. The latter develops beside the *Wolffian duct*, and, like it, empties into the lower end of the bladder or into the sinus urogenitalis.

In the *male* the *duct of Müller* disappears, only slight traces in the form of the uterus masculinus or vesicula prostatica remaining; the primitive sexual gland unites with a small part of the *Wolffian body*, which becomes the head of the epididymis, another small portion forming the vasa aberrantia testis (organ of *Giraldes*), the remainder disappears, while the *Wolffian duct* becomes the vas deferens and vesicula seminalis.

In the *female* the *Wolffian body* and its *duct* disappear, leaving only a trace in the form of the gland-tubules known as the parovarium, but remains of the duct are not infrequently found preserved in the uterine wall. From the *ducts of Müller*, which in part coalesce at their lower ends, develop the vagina, uterus, and tubes. The extreme upper end of the *duct of Müller* not infrequently persists in the form of a little pedicled sac attached to the abdominal end of the tube, the hydatid of *Morgagni*.

The anlage of the *sexual glands* appear in the fifth week. In mammalia (probably also in man) they develop through a localized thickening of the peritoneal epithelium, which becomes the germinal epithelium (*Waldeyer*), while at the same time the mesoderm also proliferates. Whether the seminal tubules arise from peritoneal epithelium

(*Bornhaupt Egli*), or whether they are derived from an ingrowth of the Wolffian body into the testis-anlage (*Waldeyer*), is still an undecided question (*Kölliker*). The ova arise from germinal epithelium. The environing cells of the Graafian follicle are regarded by *Waldeyer* as also derived from the germinal epithelium; while *Kölliker* believes that they probably arise from the Wolffian body.

The significance of the *pedunculated* and *non-pedunculated hydatids*, found in varying numbers near the globus major of the epididymis, is not yet determined (*Kölliker*). The non-pedunculated cyst known as the hydatid of Morgagni is regarded by *Waldeyer* as a remnant of the duct of *Müller*. According to *Roth*, it may also stand in a close relation to the *Wolffian* body, inasmuch as there is occasionally found a vas aberrans of the epididymis communicating with it.

In the development of the vagina and uterus the ducts of *Müller* and the *Wolffian* ducts unite at their lower portion to form a rounded quadrangular cord, the genital cord. At the end of the second month the ducts of *Müller* blend to form a single canal, which then develops into the vagina and uterus. This union takes place first near the middle of the genital cord. The *Wolffian* ducts play no rôle, though remains of these are found at birth in the broad ligament (*Kölliker*) and in the wall of the uterus (*Biegel*). According to observations of *Riedel*, remains of the *Wolffian* duct are found in about a third of adult females, in the form of a tube lined by cylindrical epithelium surrounded by muscle, or as a muscle-bundle without epithelium, lying anteriorly and to the side of the uterus and vagina.

The **external genitals** begin to develop, even before the cloaca has separated into the intestinal and genito-urinary orifices, by the formation, in the sixth week, of a median genital tubercle in front of the cloaca, and further, of two lateral folds, the genital folds. Toward the end of the second month the tubercle becomes more prominent, and shows on its lower surface a furrow, the genital furrow. In the third month the cloaca becomes divided to form the anal and genito-urinary openings. In the male embryo the genital tubercle becomes the penis, the glans being recognizable as early as the third month. In the fourth month the furrow closes to form a tube; at the same time the two genital folds unite to form the scrotum.

The prepuce is formed in the fourth month. The prostate arises in the third month as a thickening of the tissues at the junction of the urethra and the genital cord. The glands of the prostate develop in the fourth month from the epithelium of the canal and grow out into the surrounding connective tissue.

In the female embryo the closure of the genital furrow and the genital folds does not take place, so that the sinus urogenitalis remains short. The genital eminence becomes the clitoris, the folds become the labia majora, and the edges of the genital furrow the labia minora.

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## 5. DOUBLE MONSTERS.

### (a) Classification of Double Monsters.

§ 144. **Twin-formations** lying within a single chorion may be divided into two large groups: *twins completely separated from one another*, and *twins united by some portion of their bodies*.

Of the **twins completely separated from one another** there may be distinguished two types; one in which *both twins are fully developed*, and one in which *one twin is stunted*.

**Twins joined together by portions of their bodies** may likewise be also divided into two groups: *twins showing uniform development* and *twins showing an unequal development*.

According to the situation of the duplicated portions of the body, there may be distinguished (*Foerster*):

1. Monstra duplicia katadidyma or duplicitas anterior.
2. Monstra duplicia anadidyma or duplicitas posterior.
3. Monstra duplicia anakatadidyma or duplicitas parallela.

In general, these may also be conveniently divided into three classes (*Taruffi*):

1. Twins united chiefly by the epigastrium and thorax.
2. Twins united chiefly by the heads.
3. Twins united chiefly by the pelves.

Ahlfeld divides the double monsters into two chief groups, those with *complete* and those with *partial doubling of the axial structures*.

In very rare instances **triple monsters** occur.

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### (Double Monsters.)

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- See also § 130.

### (b) The Chief Forms of Double Monsters.

§ 145. **Twins separated from each other** and lying within a *single chorion* are designated **homologous twins**. They are always of the same

sex, have usually a common placenta, and resemble each other very closely. If from any cause one of the twins should die after its body has been developed, it may be pressed flat by the continued growth of its fellow, giving rise to the condition known as *foetus papyraceus*.

When twins possess a common placenta within which the blood-vessels have abundant anastomoses, the heart of the stronger foetus may control the circulation and thereby cause changes in the direction of the blood-stream in the weaker twin. As a result of this the latter suffers severe disturbances of development, and becomes changed into an *acardiacus*, a monster without a heart, either developing no heart at all or

only a rudimentary one. In the majority of such cases the head also fails to develop (*acardiacus acephalus*) or remains rudimentary (*acardiacus paracephalus*), and likewise there is usually no development, or only a rudimentary one, of the upper extremities, thorax walls, lungs, and liver, while the abdomen, pelvis, and lower extremities are more or less perfectly formed (Fig.



FIG. 399.

FIG. 399.—*Acardiacus acephalus*, showing a rudimentary development of the lower extremities (*acardiacus amorphus*).



FIG. 400.

FIG. 400.—*Acardiacus pseudoacornus*. (After Barkow.) a, Head; b, rudiment of the left upper extremity; c, rudimentary intestine; d, artery; e, vein.

399). According to the development of the extremities the following varieties may be distinguished: *acardiacus paracephalus* (or *acephalus*) *sympus*, *monopus*, *dipus*, *monobranchius*, *dibranchius*.

In rarer cases there is no recognizable development of any part of the body, and there is formed an *acardiacus amorphus*, consisting of a shapeless mass covered with skin, usually without any indications of extremities, and possessing internally only rudiments of organs.

Of very rare occurrence is the formation known as an *acardiacus pseudoacornus* (Fig. 400)—that is, a monster in which the head (a) only is developed, while the other parts of the body are represented only by small rudiments (b, c).



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See also § 147.

§ 146. Twins equally developed and united to each other occur in the following principal types:

1. **Duplicitas anterior** (*monstra duplicia katadidyma*). Anterior duplication with union of posterior portions of the body.

**Pygopagus** (Fig. 401). Union of the twins in the region of the

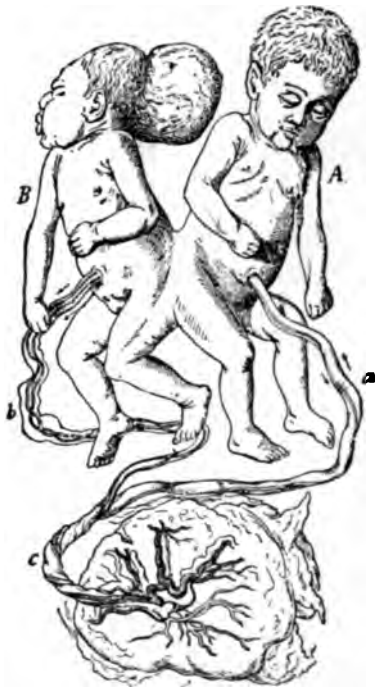


FIG. 401.

FIG. 401.—Pygopagus. (After Marchand.) A, B, The two twins; a, b, separated umbilical cords; c, blended umbilical cords; d, common placenta. There is a single coccyx and the second vertebra downward, and the lower end of the medullary canal is single. The vestibule of vagina single, the remaining parts minute.



FIG. 402.

FIG. 402.—Ischiopagus. (After Levy.)

coccyx or of the sacrum. According as the sacrum, coccyx, lower end

end of the bowel, and the sexual apparatus are either doubled or are in part single.

**Ischiopagus** (Fig. 402). Union of the twins in the pelvis, which thereby forms a wide ring, the two sacra being placed opposite each other. The anus, lower end of the bowel, and the sexual organs may be single or double, and the number of the lower extremities two to four.

**Dicephalus** (Fig. 403) and **diprosopus** (Fig. 404). The duplication is limited to the upper part of the trunk and head, or only to the neck and head, or the head alone, or, finally, only to portions of the head. As the external blending increases in extent, there occurs also a blending



FIG. 403.—Dicephalus dibrachius dipus.



FIG. 404.—Diprosopus distomus tetraphthalmus diotus dibrachius.

of the internal organs, the intestine, liver, lungs, heart, spinal cord, brain, etc. According to the number of the lower and upper extremities there may be distinguished *dicephalus tetrapus*, *dipus*, *tetrabrachius*, *tribrachius*, *dibrachius* (Fig. 403). When the heads have blended there may be distinguished *diprosopus*, *tetraphthalmus*, *triophthalmus*, *diophthalmus*, *tetrotus*, *triotus*, *diotus*, *distomus*, *monostomus*, *tribrachius* and *dibrachius* (Fig. 404).

The mildest grades of *duplicitas anterior* are represented by the rare cases of *duplication of the jaw, mouth, or nose*.

2. **Duplicitas posterior** (*monstra duplicia anadidyma*). Union of the twins at the head and thence farther downward with duplication of the posterior parts of the body.

**Craniopagus** (Fig. 405). Union of the twins in the cranial region.

According to the site of union there may be distinguished *craniopagus parietalis*, *frontalis*, *occipitalis*. When the union is more extensive portions of the brain are also single.

**Cephalothoracopagus** or **syncephalus** (Fig. 406). Blending of the twins in the region of the forehead and face, and in part also of the abdomen. In the region of the united heads there is an anterior and a posterior face (*janus*, *janiceps*). The two faces may be equally (*janus symmetros*) or unequally developed (*janus asymmetros*), one face being well developed, the other imperfectly. The internal organs present different degrees of blending and union into single organs.

**Dipygus.** The duplication is limited to the



FIG. 405.

FIG. 405.—Craniopagus parietalis.



FIG. 406.

FIG. 406.—Cephalothoracopagus or syncephalus, with janus head. Both anterior and posterior faces are malformed, and possess but one eye, while the nose is represented by a proboscis-like organ situated above the eye.

lower half of the body and the lower extremities, while the upper parts are either wholly single or only partly cleft. The duplication of the spinal cord may begin at different heights. According to the number of extremities different forms may be distinguished. The mildest grades of duplication are confined to the lower end of the spinal column, the anus, and the external genitals.



FIG. 407.—*Thoracopagus tribrachius tripus*. The hand of the third arm, common to both halves, possesses two dorsal surfaces, and the laterally distorted fingers possess nails on both sides. The common third foot has eight toes.

3. **Duplicitas parallela** (*monstra duplicia anakatadidyma*). Duplication of the anterior and posterior ends of the body with parallel positions of the trunk.

**Thoracopagus** (Fig. 407). Union of the twins by the thorax. According to the site and extent of the union, as well as the number of extremities present, there may be distinguished different forms, particularly the following: *xiphopagus* (union at the xiphoid process), *sternopagus* (union at the sternum), *thoracopagus tetrabrachius*, *tribrachius*, *dibrachius*, *tetrapus*, *tripus*, and *dipus*. When portions of the faces have blended there results a *prosopothoracopagus*. Blending and union of the internal organs into single organs vary with the degree of external blending. The heart may be double or single, in the latter case malformed. *Thoracopagus* is relatively frequent.

**Rachipagus**. Blending of the twins in the region of the spinal column is very rare.

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**Virchow**: *Pygopagus*. *Berl. klin. Woch.*, 1873.  
 See also §§ 132 and 147.

§ 147. Twins joined together but unequally developed may occur in any of the double forms described in § 146. If the development of one of the twins remains rudimentary and if its heart does not develop, its nourishment can come only through its well-developed fellow. The better developed of the two is then known as the **autosite**, the other as the **parasite**. If the parasite is of only very rudimentary development, it may be classed with the **bigeminal teratomata** (cf. §§ 128 and 129).



At the *posterior ends of the body* there may occur a rudimentary parasitic double monstrosity in the form of an *increase in the number of the extremities*, a *polymelos* (Figs. 408, 409). The supernumerary extremities may be one or two in number, and more or less well developed. The malfor-



FIG. 408.—Polymelos. (After Lancereaux.)



FIG. 409.—Polymelos. (After Liesching.)



FIG. 410.

FIG. 410.—Bigeminal teratoma of the coccygeal region (pygopus parasiticus). *a, b, c*, Extremities lying in a sac formed by the skin of the autosite.



FIG. 411.

FIG. 411.—Thoracopagus parasiticus (polymelia). Three legs spring from the pelvis; one of them has a double foot. Two upper extremities project from the anterior chest-wall.

mation may be regarded as a *dipygus parasiticus*. Further, there not infrequently occur *coccygeal teratomata* in which the presence of rudimentary extremities (Fig. 410, *a, b, c*) or of various body elements leaves no doubt that the tumor-like formation covered by the skin of the autosite is to be regarded as a double monster, a *rudimentary pygopagus*, or else as a *dipygus parasiticus*. Such a parasite is designated as an *epipygus*.

*Supernumerary extremities* (Fig. 411) may also be found upon the trunk, or there may occur a *headless trunk with extremities* (Fig. 412), or a *rudimentary thorax without extremities*, or, finally, *teratomata* which may be interpreted as *thoracopagus parasiticus* and as *dipygus parasiticus*. The malformation is also often called *epigastricus*.

The inclusion of such teratomata beneath the skin of the abdomen or thorax,



FIG. 412.

FIG. 412.—Thoracopagus parasiticus. (After Schenk von Gräfenberg.) Parasite attached to chest of autosite.



FIG. 413.

FIG. 413.—Epignathus. (After Lancereaux.)

or within the abdominal or thoracic cavities of the autosite, gives rise to the condition known as *inclusio fatalis subcutanea*, or *abdominalis*, or *mediastinalis*. The abdominal inclusion is also designated *engastricus*.

In the *region of the head* rudimentary twin-formations appear most often in the mouth cavity, forming usually an amorphous mass, firmly attached to the base of the skull, and consisting of skin, connective tissue, cartilage, bone, brain-tissue, teeth, intestinal elements and muscle, and rarely developed extremities. Such malformations are included under the designation of *epignathus* (Fig. 413).

On other parts of the head rudimentary twin-formations or bigeminal teratomata are very rare (cf. §§ 128, 129).

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(*Unequal Double Monsters.*)

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See also §§ 128, 129, 132, and 144.

## CHAPTER X.

### The Parasitic Fission-fungi and the Diseases Caused by Them.

#### I. General Considerations Regarding the Schizomycetes or Fission-fungi.

##### 1. GENERAL MORPHOLOGY AND BIOLOGY OF THE FISSION-FUNGI.

§ 148. The **Schizomycetes** or **fission-fungi**, often also designated collectively as **bacteria**, belong to the *protophytes*—that is, to the smallest simplest forms of plant-life. Many of them are so small that they stand upon the very border-line of invisibility even with the use of the highest-power objectives and eye-pieces. When occurring in animal tissues, it is often very difficult to distinguish them from the products of cell-disintegration; and often this can be accomplished only through the employment of specific reagents or staining-methods, and occasionally only through culture experiments.

The *Schizomycetes* throughout are *non-chlorophyllaceous, unicellular organisms*, but as a result of their growth and multiplication they often form colonies made up of numerous cells.

The form and character of the single cells, as well as their manner of growth, division, and multiplication, vary greatly, and at present these differences are used as a basis for the classification of bacteria. In the first class are placed the **Cocci**, often designated as *Micrococci* or as *Sphaerobacteria* (Cohn), that form of bacteria which constantly occurs in the form of *spherical or oval cells*. According to the grouping of the cells during their division, there may be distinguished six forms of cocci: *double-cocci* or *Diplococci*, *chain-cocci* or *Streptococci*, *clustered cocci* or *Staphylococci*, *tablet-cocci* or *Merismopedia*, *packet-shaped cocci* or *Sarcinae*, and *tube-cocci* or *Ascococci*.

The second class constitutes the **Bacilli** (rod-shaped bacteria) which formerly were divided by Cohn into *Microbacteria* and *Desmobacteria*, according to the length of the rods. These may also be designated as *short rods* and *long rods*. In association with the designation *bacillus* many authors use the term *Clostridium*, particularly for bacilli which during spore-formation assume spindle or club shapes. Long threads are often also called *Leptothrix*.

To the third class belong the **Spirilla** (screw-shaped bacteria). Screw-shaped forms with short, wide turns are known as *Spirilla*, those with drawn-out turns as *Vibrios*, those with a long, closely wound screw as *Spirochaetes*. According to their length the spirilla may also be divided into *short screws* and *long screws*.

All of the bacteria thus far referred to occur either in one single form or in a very limited cycle of forms of growth, and they may therefore be grouped together as **monomorphous** or **oligomorphous bacteria**. Cohn,



to whom we are indebted for the fundamental investigations regarding bacteria, united under the term bacteria only the oligomorphic forms.

Many writers, however, classify also as bacteria those organisms which during their development pass through a whole series of forms: spherical cells, as well as rods and simple and branching threads. These may be collected into a second group—the **polymorphous bacteria**—to which belong in particular the fungi known as *Streptothrix*, *Cladothrix*, *Beggiatoa*, and *Crenothrix*. Other authors (Lehmann, Neumann, Levy, Lubbarsch) classify these forms with the *Hyphomycetes* or regard them as transition forms between the latter and the *Schizomycetes*.

All of the *Schizomycetes* consist of a plasmatic **cell-contents** and a **cell-membrane**, both of which, according to Nencki, consist essentially of an albuminoid body, **mycoprotein**, which varies with the species. Many bacilli contain fat within their cell-bodies, at times so abundantly that it may be demonstrated by staining with Sudan III. Some of these bacteria (tubercle-bacillus, lepra-bacillus, and actinomycetes) show the presence of fat both when growing in living tissues and when cultivated upon artificial media; others (*staphylococcus aureus*, anthrax-bacillus, bacillus of glanders) show the presence of fat only when grown upon certain media (Sata). According to A. Fischer the cell-contents consist of a protoplasmic tube without a nucleus, but containing a central collection of fluid. Bütschli, Schottelius, and others regard the central bodies, recognizable in certain bacteria, as nuclei. According to investigations by Ziemann, Zettnow, and Feinberg, it is possible by staining with a mixture of methylene-blue and eosin (Romanowski-stain) to demonstrate in the cells of the majority of bacteria a “nuclear substance,” or “chromatin” (Ziemann, Zettnow), or “nucleus” (Feinberg)—that is, bodies of varying size lying within the bacteria, which stain red as do the nuclei of malarial plasmodia (Romanowski) or of other protozoa or of tissue-cells, while the protoplasm takes a blue color. According to Naegeli, Zopf, and others, many schizomycetes possess a membrane of cellulose or of a carbohydrate closely related to cellulose. In many forms of bacteria the membrane swells under certain conditions of growth, and forms a **capsule** having a hyaline appearance. Certain bacteria (*red sulphur-bacteria*) contain coloring matter within their cell-bodies, others (*Bacillus amylobacter*, *Spirillum amyloferum*) give at certain stages of their growth a marked reaction with iodine.

In all forms of bacteria, with the exception of the cocci, there have been observed swarming **movements** which are brought about by means of fine thread-like **flagella** attached singly at the ends or scattered over the entire bacterial cell. In addition there also occur slow oscillatory or gliding and creeping movements which are dependent upon the contractile and flexible qualities of the plasma. Both forms of motion occur only under certain conditions of nutrition and growth, and only in certain species.

**Multiplication** of bacteria takes place through a **transverse division** of cells which have previously become elongated. In some forms division can also take place in two or even three dimensions. After division the cells separate immediately or remain for a time attached to each other. When the cells remain attached after dividing transversely, **threads** are formed (*Streptococcus*, *Leptothrix*); after dividing both transversely and longitudinally, **flat, tablet-like colonies** (*Merismopedia*); after dividing in all three dimensions, **colonies resembling a solid body**

(*Sarcina*) are produced. Long threads may become segmented into shorter pieces.

According to the investigations of Buchner, Longard, and Riedlin, the period of reproduction—that is, the time from one cell-division to the next—is, in the case of the cholera-spirillum under favorable conditions of nutrition, about fifteen to forty minutes.

If resting bacterial cells, as the result of a constantly progressing reproduction or through the accumulation of neighboring cells, heap themselves anywhere in great masses, there are often formed jelly-like colonies, which are called **zoöglœa**. The jelly-like substance is formed from the membranes of the bacteria and, according to Nencki, consists of mycoprotein. The jelly masses may assume the most varied form, and occasionally reach a large size, so that the clumps, or lobulated masses, or strands may attain a diameter of one to three or more centimetres.

Under certain conditions many of the bacteria form **spores**. These are cells which are distinguished by the fact that they remain alive under conditions in which the ordinary forms of vegetation die; and, when brought into fresh nutrient solutions, are able to produce a new generation. *Spore-formation* is most frequently *endogenous*—that is, the spore arises inside the cells (particularly in bacilli), and is developed out of the cell-protoplasm, in which there appears a small granule which grows into an oblong or round, highly refractive, sharply-contoured body always remaining smaller than the mother-cell. After the death of the latter the spore is set free. *Arthrogenous spore-formation*, as observed in micrococci, is said to occur through the direct assumption of spore-qualities by individual members of a colony or of a series of generations, which at the same time remain externally unaltered or take on other morphological peculiarities.

In old cultures bacteria nearly always show **degeneration-forms**, which are swollen and distorted, and stain poorly and irregularly.

As non-chlorophyllaceous plants, the schizomycetes are restricted in their **nutrition** entirely to ready-formed **organic substances** which are soluble in water, and which are also supplied to them in an abundance of **water**. In addition they need also **various mineral substances**, especially sulphur, phosphorus, potassium or rubidium, or cesium and calcium (or magnesium, barium, or strontium).

The **carbon** necessary to their growth they are able to take from most of the carbon compounds which are soluble in water. They can also derive their carbon from dilute solutions of substances which in greater concentration are injurious to them—as, for example, from benzoic acid, alcohol, salicylic acid, phenol, etc.

Their **nitrogen** is derived from *albuminous matter*; further, from those compounds designated as *amins* (methyl-, ethyl-, propylamin), *amido-acids* (asparagin, leucin) and *amides* (oxamide, urea), as well from the *ammonia-salts* and in part also from *nitrates*. The albuminates, previous to their assimilation, are changed into peptone by means of a ferment given off from the bacteria. Free nitrogen cannot be assimilated as such. Nitrogenous and non-nitrogenous compounds are not only assimilable as such, but also in combination. The fission-fungi are able to take nitrogen from ammonia and nitric acid only in the presence of organic carbon compounds.

*Sulphur*, according to Naegeli, is essential to the schizomycetes, and they take it from sulphates, sulphites, and hyposulphites. The other *mineral substances* mentioned above are derived from various salts. If in

the case of an abundance of nutrient material there is too little water present, all further growth ceases; yet many of the fission-fungi are able to dispense with water temporarily. Spores suffer little from drying.

Some of the fission-fungi are either chiefly or wholly restricted for their food-supply to dead organisms or to solutions of organic matter, and are, therefore, classed as **saprophytes**; others are able to take their nutrition also from living animals or plants, and live as **parasites**.

If bacteria get into water which contains no food-material, many of them die in time. The spores survive the longest.

Free **oxygen** is necessary for the development of many bacteria; others can dispense with it as long as they are under favorable conditions of nutrition in other respects; others develop only in the absence of oxygen. The first are designated *obligate aërobes*, the second *facultative anaërobes*, the third *obligate anaërobes*.

The facultative anaërobes produce in part fermentation through their multiplication in the absence of oxygen; but according to the investigations of Flügge and Liborius, the phenomena of fermentation appear often to be absent. The pathogenic bacteria are, according to Liborius, facultative or obligate anaërobes.

**Carbon dioxide** has no influence upon the development of many bacteria, as, for example, upon the typhoid-bacillus and Friedländer's pneumobacillus. Upon others, on the contrary, it has an inhibitory action, as, for example, upon *Bacillus indicus*, *Proteus vulgaris*, *Bacillus phosphorescens*, the bacilli of anthrax and cholera, the pus-cocci, and others (C. Fränkel). The bacilli of anthrax, Asiatic cholera, and of rabbit septicæmia die out in a few hours in artificial Seltzer water, but anthrax-spores remain alive in it indefinitely (Hochstetter).

Intense **light** has an injurious or destructive influence upon the development of many forms of bacteria, and it is therefore possible to disinfect by means of strong light water which is infected (Buchner). The virulence of the bacillus of anthrax may be lessened by exposure to sunlight (Arnold, Gaillard). When exposed to the direct rays of the sun anthrax bacilli die in twenty-four to thirty hours, the spores survive as long as six to eight weeks (Arloing, Duclaux). According to Geisler the green, violet, and ultra-violet rays are particularly active. According to Rieder bacteria may be destroyed by the Roentgen-rays.

According to Naegeli, Hauser, Buchner, Zopf, and others, *different conditions of nutrition act in modifying the form and dimensions of the fission-fungi*. Thus, for example, bacilli cultivated in different nutrient solutions assume different lengths and thicknesses. Further, many varieties form in one medium spherical cells and short rods, while in another, on the other hand, they form long threads (Zopf). Finally, the *physiological properties may also change* with the different conditions of nutrition.

The **temperature** of the surrounding medium acts in general upon the bacteria in such a way that when it falls the life-processes of the organisms become weaker and slower, and finally cease entirely, whereas with an elevation of the temperature they rise to a certain maximum, and at a slight increase above this suddenly cease; still higher temperatures kill the fungi. The maximum of permissible temperature lies at a different height for different fungi, and is in part dependent also upon the character of the nutrient substance. There are forms of bacteria which grow well at a temperature of 55° C. or higher.

A low temperature checks development in all varieties; they fall into a state of immobility, but do not die even at great degrees of cold. The

immobility due to cold occurs at different temperatures with different varieties. The most favorable temperature for development lies between 30° and 40° C. for the anthrax bacillus; at temperatures above 44° and below 15° C. its development ceases. Many bacilli form spores only at high temperatures.

*Boiling water* and *steam* at 100° C. kill all bacteria and bacterial spores if allowed to act for some time. In dry air bacteria and their spores withstand higher temperatures, so that a temperature of 140° C. for three hours is necessary to kill the latter. Many bacteria are killed at a temperature of 60° to 70° C., provided it is kept up for a very long time.

Anthrax-spores die in boiling water in two hours, in confined steam in ten minutes. The action of steam at 105° C. for ten minutes kills all spores. *Live steam* kills all spores in ten to fifteen minutes, and penetrates very well into the objects to be disinfected (Koch, Gaffky, Löffler).

If fission-fungi find themselves in a suitable medium, their multiplication can still be brought to a standstill, since the fluid may contain **substances which hinder the growth of the bacteria or even kill them.** This effect is produced by many substances (sublimite, lysol, carbolic acid, iodine, formaldehyde, etc.)—even in comparatively great dilution. Other substances act injuriously upon the bacteria only when in stronger concentration. The point at which the multiplication is hindered is always reached at a much greater dilution than that at which the bacteria are killed. Spores are much more resistant than the vegetative forms.

Many bacteria are very sensitive to acids, so that even a slight degree of acidity hinders their growth (for example, anthrax bacilli and the Fränkel-Weichselbaum pneumococcus). Others are able to grow with a moderate amount of acid in the nutrient fluid. As a general rule they are especially sensitive to mineral acids, but the presence of a large amount of citric, butyric, acetic, and lactic acids hinders also their multiplication. In this connection belongs the fact that the products of decomposition caused by the fermentative action of the fungi are at a certain degree of concentration harmful to the development of the fungus, and finally stop its growth entirely. Thus, for example, in butyric-acid and lactic-acid fermentation the amount of butyric or lactic acid gradually formed finally checks the multiplication of the fungus. A similar result occurs in the bacterial putrefaction of albumin, since the products of the same, such as phenol, indol, skatol, phenylacetic acid, phenylpropionic acid, etc., hinder the further development of the bacteria. To alkalies the fission-fungi are less sensitive, and many can bear a rather high degree of alkalinity in the nutrient fluid, but there also exist forms which do not thrive in alkaline fluids (acetic-acid fungus).

The growth and multiplication of bacteria also cease in the presence of a superabundance of nutrient material—that is, in the case of **insufficient amount of water.** The fact that fruits preserved in sugar do not ferment and that salted and dried meats do not putrefy depends upon this fact. Food-stuffs can also be preserved through the removal of water and by the addition of substances which are dissolved in the tissue-fluids and in this way increase the proportion of the same in solid contents. The limit at which the fission-fungi and yeast-fungi cease to develop is reached at a much higher degree of humidity than for the moulds.

According to the investigations of Pfeffer and Ali-Cohen many motile



bacteria show **chemotactic properties**—that is, they are attracted or repelled by certain chemical substances dissolved in water. Bacteria swimming about in fluids collect, therefore, at places where there are chemical substances which attract. For example, typhoid-bacilli and cholera-spirilla are attracted by potato-juice (Ali-Cohen). Potassium salts, peptone, and dextrin likewise attract, but the individual forms of bacteria behave very differently toward these substances. Free acids, alkalies, and alcohol have a repelling action.

If a nutrient fluid contains other lower fungi besides the bacteria there often takes place a **competition between the different micro-organisms**; and fission-fungi, yeasts, and moulds may crowd one another out. Likewise a **reciprocal crowding between the bacteria themselves** may occur. For example, cocci may be crowded out and destroyed by bacilli, or one form of bacillus by another. This would happen when either the composition or the temperature of the nutrient medium is more favorable to one form than to the other; or also when one form of bacteria produces products which act injuriously upon the other, or when one form grows more rapidly than the other, and thereby deprives its competitor of the necessary food-supply.

According to investigations by Pasteur, Emmerich, Bouchard, Woodhead, Blagovestchensky, and others, the antagonism between many forms of bacteria is shown also in inoculation experiments on animals. By simultaneous inoculation with different bacteria the development of a pathogenic bacterium in the body of a susceptible animal may be hindered. For example, the development of anthrax bacilli may be hindered by simultaneous inoculation with erysipelas-cocci (Emmerich) or with the *Bacillus pyocyaneus* (Bouchard).

*Babes* and *Ernst*, by means of especial staining methods with *Löffler's* methylene-blue, hæmatoxylin, and *Plutzer's* nuclear black, have demonstrated the presence of *granules within different forms of bacteria*, which according to their behavior probably stand in some relation to the processes of division and spore-formation. *Ernst* designated the appearances seen by him as *sporogenous granules*, since he was able in certain bacteria to demonstrate their transition into spores; he is inclined to regard them as of the nature of cell-nuclei, a view which *Bütschli* also favors. *Bunge* regards the granules described by *Ernst* as cell-granules which have nothing to do with spore-formation, and describes other granules, which stain with *Löffler's* methylene-blue, as the forerunners of spores. *Marx* and *Woithe* regard the *Babes-Ernst* granules as not being nuclei in the ordinary sense of the word, but as representing products of the maximal condensation of the euchromatic substance of the cells, which are a sign of the highest intensity of vitality on the part of the cell. *Wagner*, on the contrary, holds that certain bodies, which he has observed in typhoid- and colon-bacilli, are nuclei.

According to *Nakanishi*, the spores form (in anthrax- and hay-bacilli) by a concentration of the chromophile substance about the nucleus, while the remaining portion of the protoplasm becomes clear; a membrane is then formed about the chromatin body, it takes on a fat-like shine, and loses its power to take stains (methylene-blue BB).

The Romanowski stain is a mixture of methylene-blue and eosin, whereby a red dye contained in methylene-blue (*Rosin, Berl. klin. Wochen.*, 1899; *Nocht, Cbl. f. Bakt.*, 1899) is precipitated. Zettnow's formula is as follows: 50 c.c. of a one-per-cent. solution of methylene-blue (Höchst) is mixed with 3-4 c.c. of a five-per-cent. soda solution. To 2 c.c. there is added drop by drop while shaking 1 c.c. of a one-per-cent. solution of eosin (Höchst BA). Stain on cover-glass for five minutes. Examine in water.

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§ 149. **The growth and multiplication of the fission-fungi give rise always to chemical transformations of the nutrient material**, which are brought about in part through the influence of *ferments produced by the bacteria*, and in part directly through the *metabolic processes occurring within the bacterial cells themselves*.

Among the **ferments or enzymes** are to be mentioned first the *proteolytic or albumin-dissolving enzymes (bacteriotrypsins)* which bring about a solution of the albuminous bodies and cause the disintegration of the peptone-molecule. Further, bacteria give rise to *diastatic ferments* which convert starch into sugar, also to *inverting ferments* which transform cane-sugar (disaccharid) into grape-sugar (monosaccharid).

The **chemical results of bacterial metabolism**, which are brought about by the vital activities of the fission-fungi aided by the enzymes produced by them, consist in the first place of a decomposition of complex organic compounds. By many authors all these processes are designated as **fermentations**, while others (Lehmann) speak of fermentation only when a fission-fungus breaks down a given food-material with especial ease, thereby giving rise to one or more especial products in marked quantity, in association with or in place of its other metabolic products. Other authors still narrow the term fermentation to the decomposition of carbohydrates.

In the **decompositions caused by the fission-fungi very different products** are formed, which vary according to the composition of the nutrient material and the character of the fission-fungus. For the production of fermentation a proper fermentable material is necessary. Many fungi are able to cause fermentation in the presence as well as in the absence of oxygen, while to some of them a lack of oxygen is necessary.

Among the **products of bacteria** of especial importance to the physician are those which **have a poisonous action and cause tissue-changes**, to which belong particularly those substances which are described as *ptomaines, toxins, and toxalbumins*.

The **ptomaines** are basic, crystallizable, nitrogenous products of the bacterial decomposition of albumin; they are also known as *putrefactive*



*alkaloids* or *cadaveric alkaloids*. When these display poisonous properties they are classed with the **toxins**. The best known are sepsin, putrescin (dimethylethylendiamin), cadaverin (pentamethylendiamin), collidin (pyridine derivative), peptotoxin, neuridin, neurin, cholin, gadinin, and substances resembling muscarin.

The **toxalbumins** are amorphous poisons, which may be precipitated from bouillon cultures containing many bacteria by the same methods that cause the precipitation of albumins. They are, therefore, regarded by most investigators as *albuminous bodies*. It should be noted, however, that they are, possibly, in part, only bodies which are carried down with the precipitated albumin; and in proof of such a conception speaks the fact that the specific poisons of tetanus and diphtheria have been shown (Brieger) to be free from albumin. It appears, therefore, more correct to designate these specific poisons as **toxins**. They constitute those poisons which determine the special form of intoxication in the various infectious diseases.

Among other decompositions produced by bacteria the following are worthy of note: the formation of lactic acid, formic acid, acetic acid, propionic acid, butyric acid, often also the formation of alcohol and carbonic acid from sugar; the formation of acids (acetic, butyric, propionic, valerianic, succinic, formic, and carbonic) from alcohol and organic acids; the formation of indol, skatol, phenol, cresol, pyrocatechin, hydrochinon, hydroparacumaric acid, and paroxyphenylacetic acid (von Nencki, Salkowski, Brieger), and finally hydrogen sulphide, ammonia, carbonic acid, and water from albumin; the formation of ammonium carbonate from urea; the transformation of nitrous and nitric acids into free nitrogen; the reduction of nitrates to nitrites and to ammonia, etc. Finally, there are also bacteria living in the soil—the nitrobacteria—which are able to form nitrous and nitric acids from ammonia (Winogradsky).

Along with the nitrification of nitrogen there occurs simultaneously a decomposition of earthy alkali carbonates, as shown by the fact that the nitrobacteria are able in the presence of organic carbon compounds to derive from the carbonates the carbon necessary to the building-up of the cells. There takes place, therefore, through the vital activity of these organisms, a synthesis of organic material out of inorganic substances.

Under the influence of the fission-fungi there are formed *bitter, sharp, nauseating substances* (bitter milk). Further, bacteria occasionally produce *pigments* of a red, yellow, green, blue, or violet color. For example, *Bacillus prodigiosus* produces a blood-red coating upon bread (bleeding bread); bandages and pus take on a bluish-green color as the result of the presence of the *Bacillus pyocyaneus*. In many cultures there is also formed a fluorescent coloring matter.

The *phosphorescence* not infrequently seen upon decomposing sea-fish depends also upon bacterial products of decomposition, as has been shown by Pflüger, and appears when there is an active multiplication of the bacteria.

The first investigations to establish the nature of the processes of putrefaction were made by Th. Schwann and Franz Schulze (*Pooggend. Annl.*, 29 Bd., ref. in *Schmidt's Jahrb.*, 1866), in the middle of the fifties, and upon the results of their experiments was based the view that fermentation and decomposition are dependent upon the presence of very small organisms. Almost at the same time (1857) Cagnard-Latour observed the increase of yeast-cells in the course of alcoholic fermentation. The observations made by Schwann were later confirmed by Helmholtz. H. Schroeder and von Dusch

then showed that by filtering through cotton-wool the air admitted to a fluid capable of fermentation, as well as by the action of higher temperatures, the appearance of fermentation may be hindered.

Since the investigations of *Schreann*, many different hypotheses as to the cause of fermentation, alcoholic fermentation in particular, have been advanced. Certain writers have endeavored to bring these processes into immediate relationship with the life of the cells causing the fermentation; others have sought to separate them from the latter. According to *Liebig*, the process is due to a molecular movement which an unformed ferment or body in a state of chemical activity—that is, decomposing—imparts to other bodies whose elements are not closely held together. According to *Hoppe-Seyler* and *Traube* (cf. *Hoppe-Seyler, Pflüger's Arch.*, Bd. xii., 1875; *Physiologische Chemie*), the cells produce certain substances, the so-called unformed ferments, which cause decomposition by contact action—that is, merely through their presence, without taking part chemically or entering themselves into combination.

According to *Pasteur* (cf. *Pasteur, Ann. de chim. et de Phys.*, tome 58, 1860, and 64, 1862; *Comptes rend. de l'Acad. des Sciences*, tomes 45, 46, 47, 52, 56, 80; and *Duchaux, "Ferments et maladies,"* Paris, 1882), fermentation is directly dependent upon the life of the cells causing fermentation. It occurs only when free oxygen is lacking to the cells, so that the latter must take oxygen from the chemical compounds in the nutrient fluid. In this way the molecular balance of the latter is destroyed. According to *von Nencki*, *anaërobiosis* is to be regarded as the cause of the different kinds of fermentation.

According to *Nägeli's molecular-physical theory* (*Abhandl. der Bayr. Akad. Math. physik.*, Kl. iii., Ser. 76, 1879), fermentation is a transfer of conditions of motion (which are present in all substances) from the molecules, atom-groups, and atoms of the different, chemically unchanged combinations constituting the living protoplasm to the material undergoing fermentation, whereby the molecular balance of the latter is disturbed and the molecules become disintegrated.

According to *E.* and *H. Buchner*, there can be obtained from yeast, by a pressure of 400–500 atmospheres, a cell-juice which causes at once fermentation of sugar-solutions. Fermentation is, therefore, not bound up with the life of the cells, but is caused by a cell-substance "zymase," which is probably secreted by the cell. This experiment has, indeed, been confirmed from other quarters, but the possibility that living protoplasm still remains in the expressed juice has not yet been excluded.

The power to produce fermentation—i.e., decomposition—in a nutrient fluid is very likely a property, not only of the schizomycetes and blastomycetes, but also of the cells of more highly organized beings, even also of man. According to *Voit* ("Physiologie des Sauerstoffwechsels," Leipzig, 1881), the decomposition of the dissolved albumin circulating in the organism is to be referred to a fermentative activity of the cells. *Pasteur* has shown that fruit and leaves also possess fermentative properties under suitable conditions.

Besides the fermentation and decomposition caused by fungi, there are other decompositions of organic substances in the production of which the fungi have no part. These consist chiefly in a slow oxidation or burning, in which carbonic acid and water are formed, and, in the case of nitrogenous substances, also ammonia. This form of decomposition takes place under conditions in which atmospheric air and moisture are in contact with organic matter. Moreover, it also takes place in the living organism. In the case of dead organic-matter, this burning corresponds in part to the process commonly called mouldering.

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 See also §§ 148 and 150.

## 2. GENERAL CONSIDERATIONS CONCERNING THE PATHOGENIC SCHIZOMYCETES AND THEIR BEHAVIOR IN THE HUMAN ORGANISM.

§ 150. As has already been explained in §§ 11 and 12 there are among the schizomycetes numerous species which are capable of causing disease-processes in the human organism, and are therefore called **pathogenic schizomycetes**. The first condition of such action is evidently that the bacteria concerned must possess properties enabling them to multiply in the tissues of the living human body. They must therefore find in the tissues the suitable nutrient material, and in the body-temperature the warmth necessary to their growth. The tissues, moreover, must not contain substances which are a hindrance to their growth (cf. §§ 30 and 32).

If pathogenic fission-fungi succeed in growing in the tissues of the body, if **infection** takes place (cf. § 12), their action is in general characterized by the production, *at the point of multiplication, of tissue-degenerations, necrosis, inflammation, and new-growths of tissue*, while at the same time the *toxins* produced by them cause *manifestations of poisoning*.

In individual cases the pathological processes vary greatly, in that the distribution of the bacteria in the organism, and their local action, as well as the production of the poisons, differ greatly with the different forms of bacteria.

With many the *local action* upon the tissue is the most prominent characteristic, with others the *general intoxication*. Many bacteria *confine themselves to the region in which they have gained entrance*; others *advance uninterruptedly upon the surrounding tissues*; others still are carried by the blood and lymph streams and lead to the formation of *metastatic foci*, and, finally, others *increase within the blood*.

If a spread of the bacteria takes place through the blood, the bacte-

ria *may pass from the mother to the fetus* during pregnancy, since the placenta forms no certain filter against pathogenic bacteria. This has been demonstrated, for example, in the case of anthrax-bacilli, bacilli of symptomatic anthrax, glanders-bacilli, spirilla of relapsing fever, typhoid-bacilli, and the pneumococcus. According to observations of Malvoz, Birch-Hirschfeld, and Latis, changes in the placenta, such as hæmorrhages, loss of epithelium, and alterations of the vessel-walls, favor the passage of bacteria. Moreover, bacteria—as, for example, anthrax-bacilli—can grow through the tissue-spaces. In general the passage of bacteria from the mother to the fetus presupposes that after the entrance of these organisms into the circulating blood of the mother, the latter shall remain alive, at least long enough to allow of the passage of the bacteria into the fetus.

The bacteria which succeed in multiplying within the human organism *die out again in many cases within a short time*; and the disease produced by them may proceed to recovery (cf. § 31). Nevertheless, it not infrequently happens that *they are preserved for a long time within the body*, and either *excite a continuous disease process*, or at times remain in a condition of inactivity, so that no pathological processes are recognizable until *after a longer or shorter period of latency, an active reproduction again takes place and manifestations of disease show themselves anew*.

Not infrequently a **secondary infection** associates itself with an infection already existing. The relation between the two infections is either that the second infection follows the first accidentally, or that through the first infection the soil is prepared for the second (cf. § 12).

Finally, there not infrequently occur **double infections**, in that two or more forms of bacteria develop coincidently in the tissues, and produce their characteristic injurious influence upon the tissues.

Each pathogenic fission-fungus has a **specific action** upon the tissues of the human organism; but, nevertheless, *different species may exert a similar action*. For example, there are various bacteria capable of producing suppuration. Only in a certain proportion of cases do the pathological tissue-changes show such specific characteristics that from these the species of the pathogenic fission-fungus can be recognized with certainty.

Further, it has been demonstrated that **pathogenic properties of bacteria are by no means constant**; that, on the contrary, their virulence varies, so that bacteria, which cause severe—that is, fatal—infections may become changed (weakened) through external influences, so that they either wholly lose their power of causing disease-processes in the organism, or at least cause only mild forms of disease. This peculiarity is not alone of theoretical interest, but is also of great practical importance. It explains to a certain extent, on the one hand, why a certain infection does not always run the same course, and, moreover, why along with severe attacks light ones also occur. On the other hand, it affords us the possibility of obtaining *material for inoculation* from attenuated cultures of bacteria, by means of which mild grades of infection or intoxication can be produced, which are able to protect the organism from severe infections or to bring about the cure of an infection already acquired (cf. § 32).

**Weakening of the pathogenic properties of a fission-fungus** can be brought about through the suitable action upon cultures of the same, by high temperatures, oxygen, light, or chemical antiseptic substances, as well as by the cultivation of the fungus in the body of a less susceptible animal. In some forms it is only necessary to cultivate the bacteria in



question for some time upon artificial media (diplococcus of pneumonia), or to expose the culture to the air for some time (bacillus of chicken-cholera), in order to bring about an attenuation. If it is desired to preserve the virulence of the pneumococcus for some time, it is necessary, from time to time, to pass the bacteria cultivated upon artificial media through rabbits, which are very susceptible. The glanders-bacilli, tubercle-bacilli, and the cholera-spirilla lose virulence when cultivated uninterruptedly upon artificial media for some time. The streptococcus of erysipelas (Emmerich) becomes so attenuated through continued cultivation in bouillon or nutrient jelly that it is no longer capable of killing even mice.

As to the nature of the attenuation of virulence of bacteria by the methods mentioned above, it is possible to give only hypotheses. If the bacteria cultivated for a long time upon artificial media change in virulence, this may perhaps be explained in part by assuming that in a series of generations the less virulent varieties, which surely often arise, gradually gain the upper hand. For the attenuation of virulence by heat, chemical agents, etc., such an explanation is not adequate. In this case there is very probably a general weakening or degeneration of the protoplasm, and in harmony with this theory is the fact that such bacteria show a diminution in energy of growth.

If the presence of bacteria be suspected in any tissue-fluid or in the tissue-parenchyma, their demonstration may first be attempted by means of a **microscopical investigation**. Occasionally this is successful by the mere examination of a drop of the suspected fluid or of a smear-preparation of the tissue-juice diluted with salt-solution or distilled water. In other cases it is necessary to employ *staining methods*, in which case cover-glass smears of the fluid are made and allowed to dry. The smeared cover-glass is then fixed by passing through the flame, and after cooling is stained. For this purpose methylene-blue is preferably employed, in a preparation of a one-per-cent. methylene-blue solution in a 1-to-10,000 solution of caustic potash. Water solutions of fuchsin and methyl-violet are also frequently used. For many bacteria there are employed especial staining methods, in which ordinarily the preparations are heavily overstained with a solution of gentian-violet or fuchsin in aniline water, or with a water solution of methyl-violet, the excess of stain then being removed by means of weak acids or by iodine and alcohol (*Gram's method*). In this way it is often brought about that the bacteria alone remain stained, often certain forms of bacteria only.

When it is desired to demonstrate the presence of bacteria in tissues, small portions of the tissue are hardened in absolute alcohol, and are then cut into the *thinnest possible sections which are stained by appropriate methods*. Here again the methods most frequently employed are those mentioned above: gentian-violet, methyl-violet, and fuchsin. Good objectives are necessary for the microscopic examination; if possible, oil-immersion lenses and illumination with substage condenser should be employed.

If through any method the presence of **bacteria** in the tissue has been demonstrated, the attempt is next made to **cultivate** them. For this purpose the methods developed by *Koch* are usually employed. These, in principle, consist in obtaining first a fluid containing the bacteria, by means of scraping the tissue or by rubbing up pieces of tissue in sterilized salt-solution. This fluid is then evenly distributed in a solution of gelatin or agar which has been liquefied by warming; and the mixture is then poured upon horizontal glass plates, solidifying as it cools. The individual bacteria, or spores, thus separated from each other develop in the firm nutrient medium.

By a proper application of this method there are obtained in the layer of gelatin various colonies (Fig. 414), which differ in appearance so that they may often be differentiated from each other by the naked eye alone. When sufficiently separated from one another, the individual colonies may be taken up by means of a fine platinum needle, and transferred either to a boiled potato, or to a sterile gelatin plate, or streaked upon the surface of the solidified nutrient fluid in a test-tube. Very often the infected needle is stuck into the solidified transparent medium contained in a test-tube.

If the culture on the gelatin plate is pure, and if the entire procedure is carried out with the necessary care and the avoidance of contamination, pure cultures may be obtained by this method. In stab-cultures, as well as in smear-cultures on potatoes or any other nutrient medium, special peculiarities often show themselves which make it pos-

sible for the experienced observer to recognize the form of bacteria. At times, however, it is necessary to make a thorough microscopic examination of the colonies.

It is evident that all the above manipulations must be carried out with care, and that absolute cleanliness of the instruments used—glass-plates and test-tubes—as well as perfect sterilization of the nutrient medium are necessary. The proper methods of sterilization in which a long-continued heating or an exposure to high temperatures plays an important rôle, are best learned in properly equipped laboratories. The necessary guidance is furnished in the various books on bacteriological methods of examination, which have recently appeared.

An infusion of meat containing peptone and gelatin is commonly employed for making plates. It consists of a watery infusion of chopped meat, to which a definite amount of peptone and salt is added. This is further neutralized with carbonate of soda, and enough gelatin is added to give a solid consistence at ordinary temperatures. For streak- and stab-cultures this same gelatin is sometimes used; at other times a jelly made of a mixture of a watery extract of meat, peptone, and agar-agar; or again blood-serum which has been coagulated by warming.

For stab-cultures the jelly is allowed to solidify within the test-tube in a perpendicular position; for streak-cultures the test-tube is kept in an oblique position until the jelly is set.

Sterilized bouillon is often used for cultures. The inoculated nutrient media are kept either at room-temperature or at higher temperatures in an incubating oven



Fig. 414.—Gelatin plate containing pellicle-like, sinate colonies of small bacilli, and small, spherical, white colonies of cocci. Culture made from the exudate of a purulent peritonitis. Reduced one-third.

(30°–40° C.). The proper nutrient medium to be used in individual cases must be determined by experiment. Experience has shown that the individual bacteria behave very differently in this respect, some growing best upon one, others upon another medium. To the nutrient medium there are often added with advantage such substances as sugar, glycerin, urine, brain-substance, etc.

It is self-evident that the processes briefly described above may be modified according to the necessities of the case. For example, in those cases in which it is necessary to grow the bacteria at high temperatures, the use of gelatin should be avoided and agar-agar plates should be made instead. Occasionally membranes or exudates from mucous surfaces (diphtheria) or small bits of excised tissue are placed directly into the culture-medium. When it is desired to examine the cultures directly under the microscope, cultures may be made upon glass-slides. In the case of many bacteria, as cholera-spirilla, the use of hanging-drop cultures is advised. In this method a drop of sterilized bouillon hangs down from the under surface of a cover-glass, and is inoculated from a previously cultivated pure culture of the fungus. The cover-glass is then placed over the excavation in a hollow ground-glass slide. Evaporation is prevented by the exclusion of the outer air from the cavity in the slide, by a rim of oil or vaseline placed beneath the edge of the cover-glass. By this method the multiplication of bacteria can be observed for a long time.

When bacteria are sought in water, a definite amount of the suspected water is dis-



tributed in gelatin, and plate-cultures are made. *Earth* is rubbed up with sterilized salt-solution; *air* is made to pass in definite amount through a sterilized salt-solution; and the salt-solutions thus infected are then mixed with gelatin, and from this gelatin plates are made.

The culture of bacteria on and in different media, accompanied by the microscopic examination of the different stages of development, serves for a more exact characterization, and thereby for the differentiation of the species of the bacteria in question. After its properties have been thoroughly studied in this way, the influence of the bacterium upon the animal organism is tested. As experimental animals, rabbits, dogs, guinea-pigs, rats, mice, and small birds are most frequently employed. The bacteria to be tested are introduced, sometimes under the skin, sometimes directly into the blood-current, sometimes by inoculation into the internal organs, sometimes by inhalation into the lungs, or sometimes by administration with the food into the intestinal canal. Bacteria can be regarded as pathogenic for a given animal when they multiply within the tissues and excite disease processes. If relatively large amounts are inoculated, the animal experimented upon may die under certain conditions, even if the bacteria do not increase at all in its body, since the poisonous substances formed in the culture and introduced by inoculation often suffice to kill the animal.

Experience has taught that only some of the bacterial infections which occur in man, when inoculated into animals, run the same course as in man, and, indeed, only those which also occur otherwise in animals. In other cases the pathogenic fission-fungi occurring in man or in certain animals are, it is true, pathogenic for the experimental animal, but the pathological process shows another localization and another course. In a third case the experimental animals are in part or wholly immune.

Inversely, fission-fungi that are often extremely pathogenic for the experimental animals are harmless for other animals or for man.

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## II. The Different Forms of Bacteria and the Infectious Diseases Caused by Them.

### I. THE COCCI, OR SPHÆROBACTERIA, AND THE MORBID PROCESSES CAUSED BY THEM.

#### (a) General Considerations Regarding the Cocci.

§ 151. The **cocci** or **coccaceæ** (Zopf) are bacteria that occur exclusively in the form of round or oval or lanceolate cells. In their multiplication by division they often form peculiar aggregations of cells, which are commonly designated by special names according to the character of the different forms appearing. Since certain forms of cocci are especially likely to develop in definitely shaped aggregations, advantage has been taken of this fact, to classify them in different **species**. It should be noted, however, that a given species does not always appear in the same form, but may vary according to the nutrient conditions.

Many of the cocci multiply by division in one plane only—at right angles to the length of the elongated spherical cell. If the spheres resulting from division remain together for some time in the form of double spheres, and if this form appears with especial frequency in the case of any one species, it is designated as a **diplococcus**



FIG. 415.



FIG. 416.



FIG. 417.



FIG. 418.

FIG. 415.—*Streptococcus* from a purulent peritoneal exudate of a case of puerperal peritonitis. *a*, Single cocci; *b*, diplococci; *c*, streptococci or torula-chains.  $\times 500$ .

FIG. 416.—Colonies of micrococci in blood-capillaries of the liver, causing metastatic abscess-formation. From a case of pyæmia. Necrosis of liver-cells.  $\times 400$ .

FIG. 417.—Cocci grouped in tetrads (*merismopedia*), from a softening infarct of the lung.  $\times 500$ .

FIG. 418.—*Sarcina ventriculi*.  $\times 400$ .

(Fig. 415, *b*). If, from a further continued division of the cells in one plane, rows of cocci (*torula chains*) result, these are known as **streptococci** (Fig. 415, *c*), and this term is used also as the name for a group. If the division of the cells takes place irregularly, and the cells remain together in small collections or heaps, the bacteria are usually designated as **micrococci** (Zopf) (Fig. 416). By Ogston and Rosenbach the name **staphylococcus** or *grape-coccus* has been used to indicate some of these forms. Larger collections of cells, which are held together by a gelatinous substance derived from the cell-membranes, have been designated as *zoöglæa* masses. If the masses of cocci are united into larger collections by means of a gelatinous envelope, they are spoken of as *ascococci* or *tube-cocci*.

To those cocci which remain united for a long time in a four-celled tablet (Fig. 417), the name of **merismopedia**, **tetracoccus** or **tablet-coccus**

was applied by Zopf. Others class such bacteria with the micrococci. The cocci that go by the name *sarcinæ* are characterized by division in three directions of space, so that compound cubical packets of spherical cells are formed from tetrads (Fig. 418).

The cocci not infrequently show a tremulous molecular motion in fluids; swarming movements have not been observed with certainty. Spore-formation has not been demonstrated in the majority of forms. According to Cienkowski, Van Tieghem, and Zopf, the *Coccus (leuconostoc) mesenterioides*, that produces a frog-spawn-like culture on sugar or parsnips, forms arthrogenic spores, in that some particular cell in a torula chain becomes larger and glistening. According to Prazmowsky the *Micrococcus ureæ* also forms spores.

The **saprophytic cocci** grow upon very different nutrient substrata and cause by their growth in suitable media various processes of decomposition. Many also form pigments. *Micrococcus ureæ* (Pasteur, Van Tieghem, Leube) causes fermentations in urine by means of which ammonium carbonate is formed from the urea. *Micrococcus viscosus* is the cause of the slimy fermentation of wine. The cause of the *phosphorescence of decomposing meat* was found by Pflüger to be a micrococcus that forms slimy coatings on the surface of the meat.

Of the pigment-producers the best known are *Micrococcus luteus*, *Micrococcus aurantiacus*, *Sarcina lutea*, *Micrococcus cyaneus* and *Micrococcus violaceus*, which, when grown upon boiled eggs or potatoes, produce yellow, blue, and violet pigment respectively.

Saprophytic cocci are found in the mouth cavity and intestine, as well as on the surface of the skin, and occasionally also in the lungs. *Micrococcus hæmatodes* (Babes) is said to be the cause of red sweat, and forms red zoöglæa masses.

**Sarcina ventriculi** (Fig. 418) occurs not infrequently in the stomach of man and animals, especially when abnormal fermentations are going on. According to Falkenheim the stomach sarcines can be cultivated upon gelatin, and form in this medium round, yellow colonies, which contain colorless monococci, diplococci, and tetrads, but never cubical packets. They form these, however, in neutralized hay-infusion, and their growth causes a souring of the infusion. The membrane of the sarcinæ is said to consist of cellulose.

**Microcococcus tetragenus** (*merismopedia*) is not infrequently found in human sputum, and in the mouth and throat; it may be present further in the wall of tuberculous cavities, or in hæmorrhagic or gangrenous foci of the lungs. It forms tetrads (Fig. 417) whose cells are held together by a gelatinous membrane. On gelatin-plates it forms round or oval, lemon-yellow colonies. It is pathogenic for white mice and guinea-pigs, to a less extent for rabbits, and, when injected subcutaneously, excites purulent inflammations, in the mouse often also a septicæmia. Intratracheal injections may give rise to inflammations of the respiratory passages and the lungs.

The **pathogenic cocci** cause acute inflammations which usually heal after the death of the bacteria; but it not infrequently happens that cocci may remain in the body for a long time and give rise to chronic processes.



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 See also § 148.

## (b) The Pathogenic Cocci.

§ 152. The *Streptococcus pyogenes* (Rosenbach) is a coccus which, in multiplying, forms *double spheres* and *chains of spheres* (Fig. 415) of different lengths, containing from four to twelve or more cells. This chain-formation comes to an especially full development when the streptococcus is growing in fluids—in nutrient bouillon or fluid exudates—but is also usually seen when it is growing within the tissues.

The cocci stain well by Gram's method, are facultative anaërobes, grow best at 37° C., and form small whitish colonies on gelatin and agar.

The streptococcus pyogenes is especially pathogenic for mice and rabbits (much less so for dogs and rats); but its virulence varies greatly, and rapidly decreases in cultures grown on ordinary media. Its virulence is retained for a relatively long time (Marmorek) in cultures of the cocci in human- or in horse-serum (serum two parts, bouillon one part), or in a mixture of bouillon and ascitic fluid.

*Streptococcus pyogenes* causes in man **inflammations, which usually, though not always, assume a purulent character.** Occasionally it is found also upon normal mucous membranes, for example, in the upper air-passages, or in the vagina and cervix uteri; it may therefore be assumed in such cases that its virulence is very slight, or that the mucous membranes offer a successful resistance to its entrance into their tissues.

An infection with streptococci may occur either in healthy individuals, or in those who have received some injury, or finally as an accompaniment and sequela of other infections, particularly of scarlet fever, diphtheria, and pulmonary tuberculosis.

If the streptococcus multiplies upon the *surface of mucous membranes*—for example, of the respiratory tract (Fig. 419)—it excites an *inflammation*, which may bear the character of a *desquamative* or *purulent catarrh*.

(c), or of a *croupous exudation* (d). If it penetrates into the connective tissues of the submucosa, it causes most frequently inflammations which

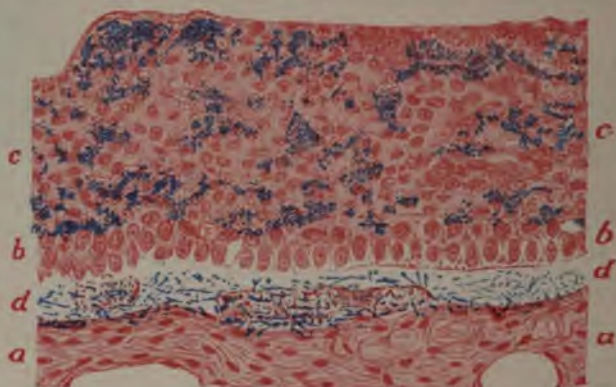


FIG. 419.—*Streptococcus tracheitis* in scarlet fever (alcohol, carmine, methyl-violet, iodine). *a*, Connective tissue; *b*, desquamated epithelium; *c*, membrane composed of cells and streptococci; *d*, fibrin threads.  $\times 300$ .

are *phlegmonous* in character—i.e., a more or less quickly spreading, sero-purulent, or purulent, or fibrinopurulent, or serofibrinous inflammation, which may at certain points lead to suppuration and abscess-formation. In the exudate the cocci may be found in part free (Fig. 420, *c*), or in part inclosed within cells (*b*).

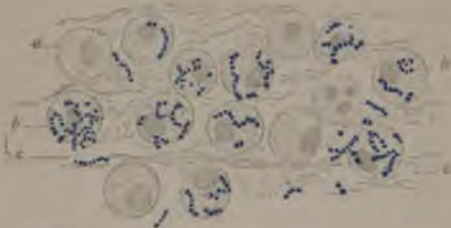


FIG. 420.—*Streptococcus pyogenes* from a phlegmonous focus of the stomach (alcohol, carmine, methyl-violet, iodine). *a*, Leucocytes; *b*, leucocytes containing streptococci; *c*, free streptococci.  $\times 500$ .

If the streptococcus spreads in the *corium*, into which it penetrates especially in the case of small wounds of the skin, it utilizes the lymph-spaces and lymph-vessels (Figs. 421, *a*; 422, *b*, *i*; 423, *e*) as pathways and as places for the development of colonies, causing a more or less severe inflammation, which is

characterized macroscopically by an advancing redness and swelling of the skin known as *erysipelas*. To the external appearances there corresponds a more or less severe serous and cellular infiltration (Figs. 421, *d*, *e*, *f*; 422, *m*; 423, *c*), and often also a fibrinocellular exudation (Fig. 422, *m*). The infection of the lymph-vessels in erysipelas involves at times chiefly the superficial layers of the cutis (Fig. 422), at other times the deeper layers (Fig. 423, *c*). In the latter case the erysipelatous process becomes phlegmonous in character, so that between the two proc-

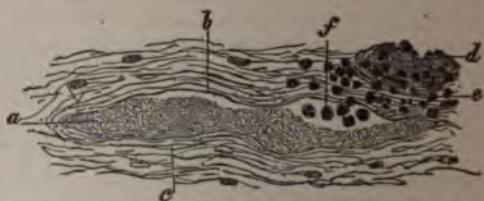


FIG. 421.—*Streptococcus erysipellatis* (*a*) inside a lymph-vessel (*b*), in part composed of thickly crowded spheres, in part of torula-chains (alcohol, gentian-violet); *c*, neighborhood of the lymph-vessel, with pale, non-staining nuclei; *d*, vein; *e*, perivascular cellular infiltration of tissue; *f*, accumulation of cells in the lymph-vessel. Section of rabbit's ear two days after inoculation with erysipelas-cocci.  $\times 225$ .

esses a sharp border-line cannot be drawn. At the same time with the infection of the deeper layers streptococci may spread on the surface of the epithelium—that is, beneath the horny layer (Fig. 423, *g*), and cause



FIG. 422.—Section of the skin in erysipelas bullosum (alcohol, alum-carmin). *a*, Epidermis; *b*, corium; *c*, vesicle; *d*, covering of vesicle; *e*, epithelial cells containing vacuoles; *f* swollen cells with swollen nuclei; *g*, cavity caused by the liquefaction of epithelial cells, and containing fragments of epithelium and pus-corpuscles; *h*, lymph-vessel, partly filled with streptococci; *i*, lymph-vessel filled full of streptococci; *k*, colony of streptococci in the tissue; *l*, *l*<sub>1</sub>, necrotic tissue; *m*, cellular; *m*<sub>1</sub>, fibrinocellular infiltration; *n*, fibrinocellular exudate in the vesicle.  $\times 60$ .

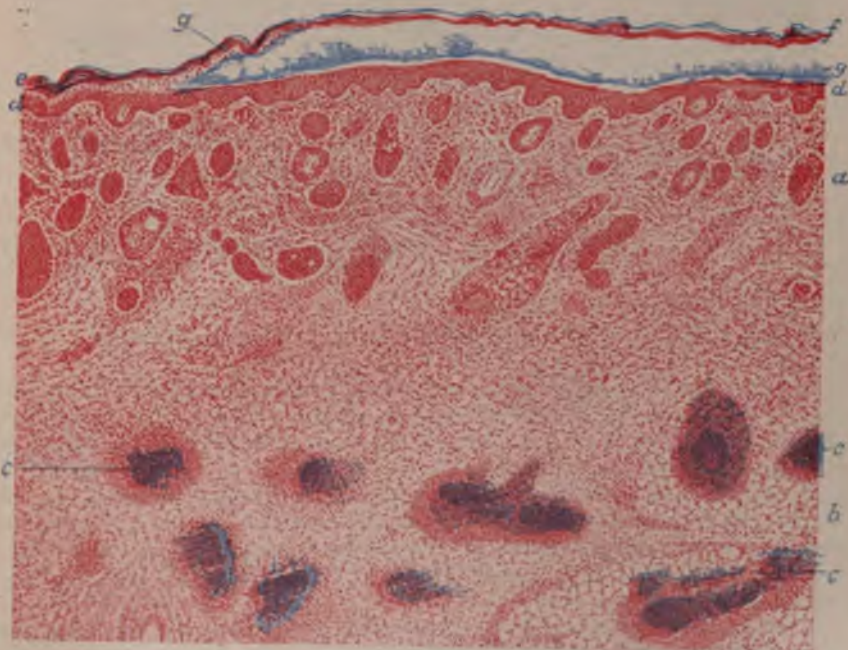


FIG. 423.—Erysipelas of the head in a child of one month of age (bacterial staining, carmine). *a*, Cytis with hair-follicles; *b*, subcutis; *c*, lymph-vessel with streptococci and inflamed surrounding area; *d*, rete Malpighii; *e*, *f*, horny layer; *g*, streptococci lying upon the rete Malpighii.  $\times 45$ .



a loosening of the epithelial cells and a desquamation of the horny layer (*f*). In cases of severe infection with very virulent streptococci the process may go on to liquefaction of the epithelium (Fig. 422, *c*, *f*, *g*, *g*<sub>1</sub>), and to the formation of vesicles (*c*, erysipelas bullosum), or to ne-



FIG. 424.—Beginning streptococcus phlegmon on the trunk, after phlegmon of the arm (formalin, carmine, methyl-violet). *a*, *b*, skin; *c*, streptococci in the subcutaneous connective tissue; *d*, beginning collection of leucocytes.  $\times 15$ .

erosis and gangrene of the corium (*l*, *l*<sub>1</sub>, erysipelas gangrænosum), or to suppuration of the tissue.

In the *subcutaneous tissue* the spread and multiplication of the cocci (Fig. 424, *c*) lead to a progressive seropurulent (*d*) and fibrinopurulent inflammation, often with subsequent tissue-suppurative. Such forms of infection are known as *phlegmons*.

If the *muscles* become involved in a *phlegmonous process*, the streptococci increase and spread chiefly in the connective tissue of the perimysium internum, but may penetrate also into the sarcolemma-tubes. Here also the consequences of the infection are more or less severe inflammations leading to *suppuration*.

*Bronchogenous infection of the lungs* causes purulent, or croupous, or hæmorrhagic exudations into the pulmonary alveoli.

Should bone become involved from the skin or from a mucous membrane—as, for example, from the middle ear—the cocci may increase in



very large numbers in the marrow tissue (Fig. 425, *a, b*), and here give rise in the first place to tissue-necrosis, and later to a purulent inflammation of the neighboring tissues.

A streptococcus infection may terminate, either sooner or later, in that the opposing forces of the organism restrict the further spread of the bacteria, and destroy them. Not infrequently, however, the infection progresses up to the time of death.

If the streptococci break into the lymph- and blood-vessels, *metastases* are often formed, and distant organs are in this way involved. Infection of the lungs leads easily to infection of the pleura. Infection of the female genital tract, which easily takes place during delivery and the puerperium, leads very often to a spread of the infection to the peritoneum by means of the lymphatics. Infection of the serous membranes lead usually to a seropurulent, or fibrinopurulent exudation, the streptococci developing luxuriantly in the free exudate, and forming long chains. In infection of the blood, the streptococci do not increase in the circulating blood, but at the points where they come to rest; in the small capillaries of the lungs, heart, liver, kidneys, spleen, bone-marrow, joints, etc., or even on the valves of the heart. At the point of increase there is likewise produced an inflammation, which in general bears the same character as the primary inflammation, but is not infrequently less severe and more circumscribed.

*Hæmatogenous streptococcus-infection* of the lung leads to the formation of inflammatory foci (Fig. 426, *a*), which for the greater part show a



FIG. 425.—Streptococcus infection of the petrous portion of the temporal bone, from a child of eight months of age (formalin, nitric-acid decalcification, carmine, methyl-violet). *a*, Medullary spaces completely filled with streptococci; *b*, beginning invasion by streptococci; *c*, bone marrow; *d*, trabeculae of bone  $\times 300$ .

central suppuration. Collections of streptococci on the surface of the endocardium of the valves or of the heart-wall (Fig. 427, *a*) lead to a superficial necrosis and further to the formation of coagula (*b*), collec-

tions of leucocytes (*b*), and proliferations of granulation tissue (*c*, *d*). A deeper infection with the streptococci causes an extensive necrosis of the tissue accompanied by an inflammation of the surrounding tissues. If streptococci are carried by the blood-stream into the coronary arteries, there are produced in the heart-muscle inflammatory foci, which are usually purulent in character.

If the cocci pass to a blood-vessel of the skin or subcutaneous tissue, they may increase in the same to such an extent that they form perfect casts of the capillaries (Fig. 428, *c*). As the result of the surrounding hyperæmia there are produced in the skin red spots and swellings, and eventually purulent foci. In the *kidneys*, in whose vessels there often occurs an extraordinary multiplication of streptococci (Fig. 429, *a*, *b*),

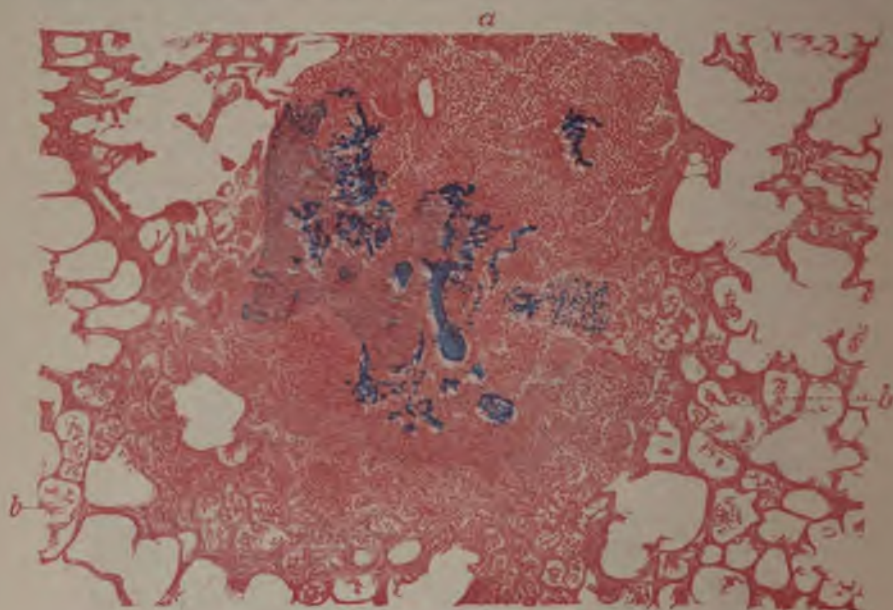


FIG. 426.—Metastatic hæmatogenous streptococcus pneumonia, after angina (alcohol, alum-carmin, methyl-violet, iodine). *a*, Pneumonic focus with (blue) streptococci; *b*, slightly inflamed lung tissue about the focus.  $\times 80$ .

there arise in the first place grayish-yellow circumscribed areas of discoloration, which are dependent upon the collection of bacteria, the local anæmia, tissue-necrosis, and often a beginning serofibrinous exudation (*d*). Later, yellow discolorations and softening of tissue appear, corresponding to suppuration. Similar changes may be demonstrated also in other organs.

The danger of a streptococcus infection depends partly upon the severe progressive local changes and the formation of metastases, and partly upon the accompanying intoxication by toxins (*toxalbumins*), which finds expression in the fever and the severe general symptoms. If the symptoms of intoxication are very prominent the condition is designated **septicæmia**. A predominance of metastatic suppuration leads to the form of disease designated as **pyæmia**. A combination of both conditions is known as **septicopyæmia** or **pyosepthæmia** (cf. § 12).



The course of a streptococcus infection, as well as the mode of entrance of the cocci into the body, can usually be recognized, since the infection ordinarily starts in the injured outer skin or from deeply pene-

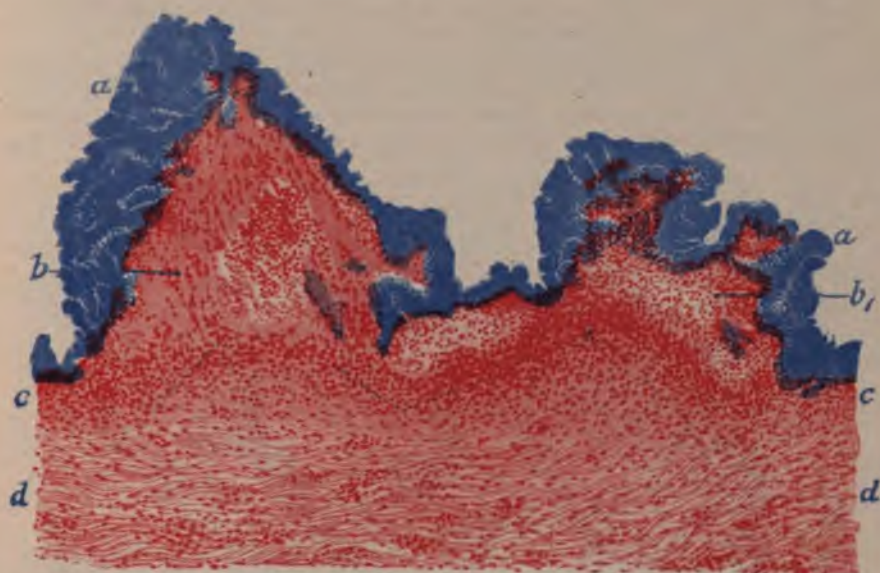


FIG. 427.—Endocarditis of the wall of the left auricle, due to streptococci (alcohol, methyl-violet, carmine). *a*, Masses of cocci; *b*, *b*<sub>1</sub>, leucocytes and coagula; *c*, area of proliferation; *d*, inflamed endocardium.  $\times 100$ .

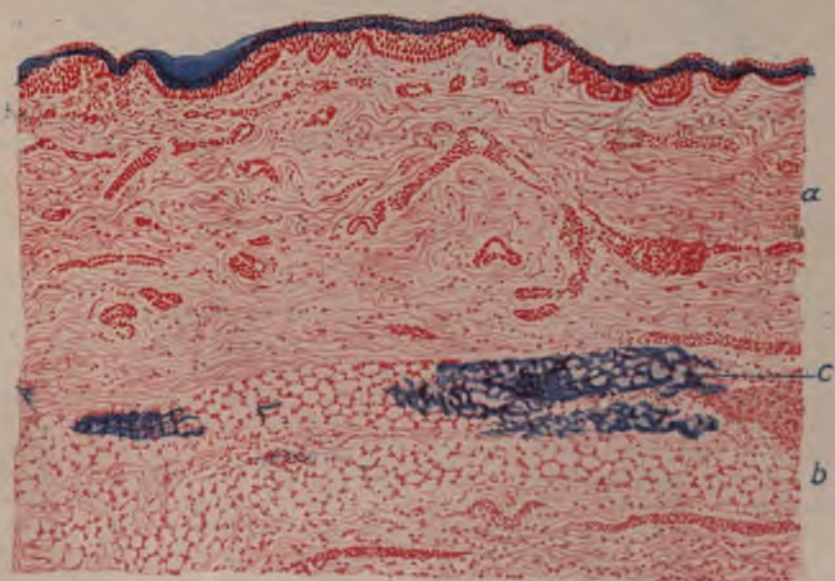


FIG. 428.—Erythema multiforme, due to streptococcus infection, arising in the middle ear (Fig. 425), from a child eight months old. Section through a red spot in the skin of the back of the foot (alcohol, methyl-violet, carmine). *a*, Corium; *b*, subcutaneous tissue; *c*, capillaries filled with streptococci.  $\times 46$ .

trating wounds, from the mucosa of the upper digestive and respiratory tracts, or from the genital apparatus as the result of changes due to child-birth. **Cryptogenic infection** is, however, not rare; in such cases the first symptoms recognizable or at least noticed clinically are those dependent upon the disease of an internal organ, so that it appears as if the infection was primary in this organ.

The individual foci of disease in streptococcus infection may present very different degrees of severity of inflammation; and this is dependent partly upon the virulence of the bacteria, partly upon the individual differences of the infected persons, partly upon the seat of the infection,

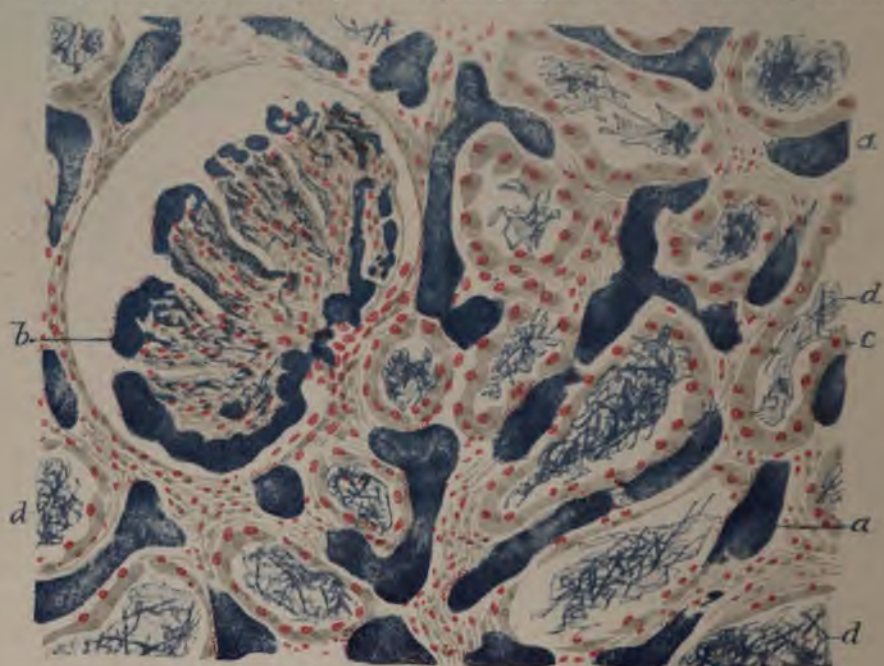


FIG. 429.—Extreme streptococcus infection of the kidney (grayish areas), arising after streptococcus angina (alcohol, Weigert's stain). *a*, Cocci in the intertubular; *b*, in the glomerular capillaries; *c*, urinary tubules; *d*, fibrin in the urinary tubules.  $\times 230$ .

and partly upon the influence of preceding or accompanying pathological conditions. As regards this last factor it may be noted that many infectious diseases (diphtheria, scarlatina, tuberculosis, typhoid fever, influenza) which lower the body resistance increase the predisposition to streptococcus infection. In the case of the growth of streptococci upon the surface of the endocardium, the inflammation often bears a very pronounced proliferative character (Fig. 427, *d*, *c*). In hæmatogenous streptococcus-dermatitis (Fig. 428) the process may cease with the formation of red spots. Phlegmons, which usually run a rapid course and lead in a short time to tissue-necrosis and suppuration may (Reclus, Kusnetzoff, Krause, Chiari) also have a very chronic course, particularly in the neck, and are then characterized by a progressive swelling and induration of the affected area, so that the affection may be designated a "wooden phlegmon" (Reclus). Fever may be wholly absent. The pro-



ess consists of a progressive proliferation of granulation tissue and a new-formation of connective tissue due to streptococci (or staphylococci), while suppuration is absent or confined to circumscribed areas.

The biological characteristics of the *Streptococcus pyogenes* are very variable, and this is well shown both in its behavior as a disease-producing agent and in the cultures of streptococci taken from different cases. Consequently an effort has been made to divide the streptococci into different species, and in particular has the streptococcus which causes erysipelas been regarded as a distinct form—the *Streptococcus erysipelatis*. Further, according to the place in which the streptococcus was found, it was formerly customary to speak of a *Streptococcus puerperalis* (Arloing), *Str. articulorum* (Flügge), *Str. scarlatinous* (Klein); or, according to the manner of growth, of a *Str. longus* and *Str. brevis*, etc. (von Lingelsheim). These characteristics are, however, not sufficient to form a basis for the separation of the streptococci into different species; and it appears more correct, or at least more expedient, to consider all the chain-forming streptococci as one species, which appears in many varieties.

In diphtheria and scarlet fever, streptococcus infections of the throat and air-passages are extremely common, particularly in the case of the first named, so that many authors (Baumgarten, Dahmer) are inclined to assign to the streptococcus a co-ordinate position with the diphtheria-bacillus in the causation of diphtheria—the diphtheria-bacilli predominating in the lighter forms of infection, the streptococci in the more severe. Pure streptococcus infections may present the same picture as that produced by the Löffler's bacillus. If both forms of bacteria are present, their effects may be combined; perhaps also the presence of streptococci increases the virulence of the diphtheria-bacilli.

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§ 153. The *Diplococcus pneumoniae* (Fränkel, Weichselbaum), or *Streptococcus lanceolatus* (Gamaleïa), or *Diplococcus lanceolatus* (Foa, Bordoni-Uffreduzzi), and also known as the *Pneumococcus*, is a pathogenic streptococcus of very frequent occurrence. It forms spherical, oval, and lanceolate cocci (Fig. 430, *a*), which in the human body are usually surrounded by a transparent capsule, and are grouped together in pairs (*b*, *d*), or more rarely in chains of such pairs (*c*), or in large colonies (*d*).

The *Diplococcus pneumoniae* stains well with fuchsin and with gentian violet, and by these stains the capsule may be demonstrated in smear-preparations. The cocci are also stained by Gram's method.

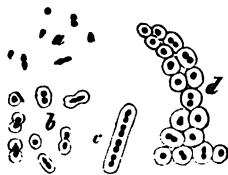


FIG. 430.—*Diplococcus pneumoniae*. (Weichselbaum.) *a*, Cocci without capsule; *b*, single and double cocci with a gelatinous capsule; *c*, chain of encapsulated cocci; *d*, colony of cocci.  $\times 500$ .

The cocci are facultative anaerobes. They will not grow upon gelatin at ordinary room-temperature, but do so upon slightly alkaline blood-serum-gelatin, upon agar and in bouillon, at a temperature above 22° C., and best at the temperature of the body. They form upon the surface of the medium a delicate, translucent, glistening culture, which suggests the dew-like deposit of moisture upon a cover-glass (Fränkel); and consists of diplococci and chain-cocci without capsules. The growth is, however, scanty; and easily dies out. Upon potatoes the cultures do not thrive.

The *Diplococcus pneumoniae* is in a great number of cases (according to Weichselbaum in seventy-one per cent.) the cause of the affection of the lung known as *croupous pneumonia*, in which the lung is the seat of an acute inflammation which is ushered in by a congestive hyperæmia (Fig. 431, *a*). In the course of the disease the alveoli over large areas of the lung become filled with a coagulated exudate consisting of desquamated epithelium, leucocytes, red blood-cells, serous fluid and fibrin (Fig. 195). In the normal course of the disease the exudate becomes liquefied and absorbed. As has been shown by numerous observations, the *Diplococcus pneumoniae* may also cause in the lungs other inflammatory processes bearing the character of a catarrhal bronchopneumonia, which is characterized by the formation of foci of a serocellular exudate. During the course of the disease the cocci are found especially in the inflamed areas, in the greatest numbers at the beginning of the inflammation;

they lie in part free in the alveoli (*b*) and in part clinging to cells (*d*). They are found also in parts of the lung bordering upon the inflamed area, in the pleura, and under certain conditions also in the pericardium, peritoneum, meninges, accessory nasal cavities, cellular tissue of the neck, in the mediastinum, submucosa of the soft palate and pharynx, and even in the conjunctiva itself (Weichselbaum). In all these places they may give rise to inflammatory changes. At times they may be demonstrated in the juice of the spleen, and in the blood, and in pregnant women may pass into the fetus (Viti). Under certain circumstances they may be *widely distributed throughout the body*; and may cause, in the meninges, pleuræ, pericardium, and peritoneum, fibrinous, sero-fibrinous, and at times seropurulent, and fibrinopurulent inflamma-

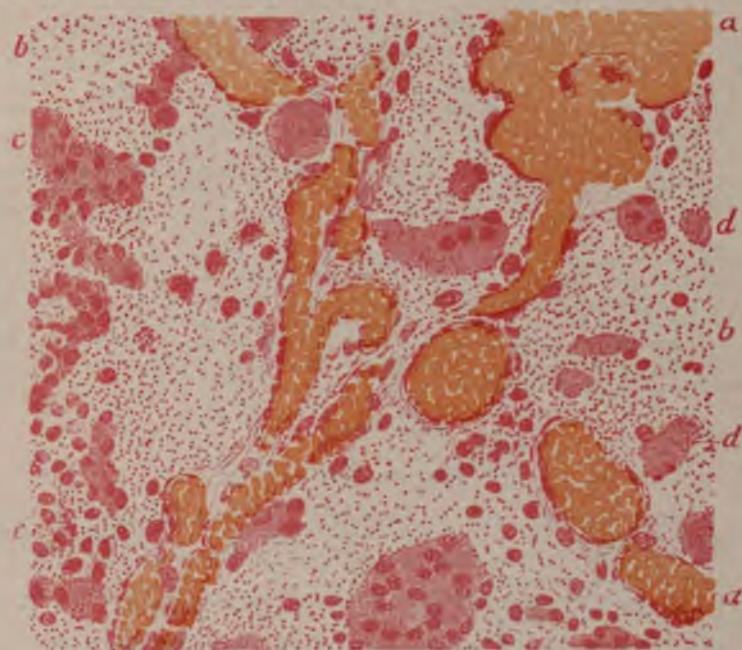


FIG. 431.—*Diplococcus pneumoniae* in early stage (fuchsin). *a*, Hyperemic vessels; *b*, diplococci; *c*, cellular exudate; *d*, swollen epithelial cells covered with cocci.  $\times 500$ .

tions, without giving rise to a pneumonia. Further, they may cause inflammations of the endocardium, kidneys, joints, tubes, endometrium, parotid, thyroid, bone-marrow, and periosteum, and these inflammations may lead to suppuration. In many cases the mouth and nasopharynx appear to be the avenue of entrance—in these regions the cocci are not infrequently found, even in healthy individuals (Weichselbaum, Fränkel). Correspondingly, in cerebral and cerebrospinal meningitis (Weichselbaum) the maxillary cavities, tympanic cavity, and the ethmoid labyrinth often contain exudates with diplococci. They are found in the exudates in all the forms above mentioned; and the gelatinous capsule may present a very variable thickness.

When inoculated into rabbits, guinea-pigs, and mice, the cocci increase in the form of encapsulated cocci, particularly in the blood and serous cavities, and may cause pneumonia with bloody serous exudate.

When injected beneath the skin of the rabbit's ear (Neufeld) they also produce erysipelatous inflammations. Rabbits are especially susceptible, as they die with symptoms of septicæmia in from thirty-six to forty-eight hours after subcutaneous inoculation. The injection of pure cultures into the pleural cavity of rabbits gives rise to a pleuritis, as well as a splenization of the lung, in which the parenchyma of the organ is filled with a hæmorrhagic serous exudate.

According to A. Fränkel the cocci very easily lose their virulence, particularly when cultivated upon milk; and if it is desired to retain their virulence they must, from time to time, be passed through susceptible animals. Cultivation of the cocci at 42° C. for one to two days destroys their virulence.

The *Diplococcus pneumoniae* belongs to those bacteria whose physiological properties are very variable. Foà distinguishes, according to the principal places in which they are found, a *pneumococcus* and a *meningococcus*. In *cerebrospinal meningitis* cocci are found which are closely related in part to the *Streptococcus pyogenes* (*Streptococcus meningitidis*, Bonome), and in part to the *Diplococcus pneumoniae* (*Diplococcus intracellularis meningitidis*, Weichselbaum). Whether these represent especial forms or only varieties of the species mentioned has not at the present time been decided with certainty. Jäger is of the opinion that the *Diplococcus intracellularis meningitidis* is the cause of epidemic cerebrospinal meningitis, and is entirely distinct from the pneumococcus. Sporadic meningitis may, on the other hand, be caused also by the pneumococcus.

According to Emmerich, there is formed in bouillon-cultures of pneumococci a sediment, which contains resistant cells which remain capable of development for months. Rabbits may be made completely immune (Emmerich) by repeated injections of highly diluted (five hundred fold) cultures of increasing virulence, so that 80 c.c. of cultures of full virulence may be borne without any striking disturbance. The injected bacteria die in the course of a few days. The serum of immunized rabbits can cure pneumococcus infections in rabbits and mice.

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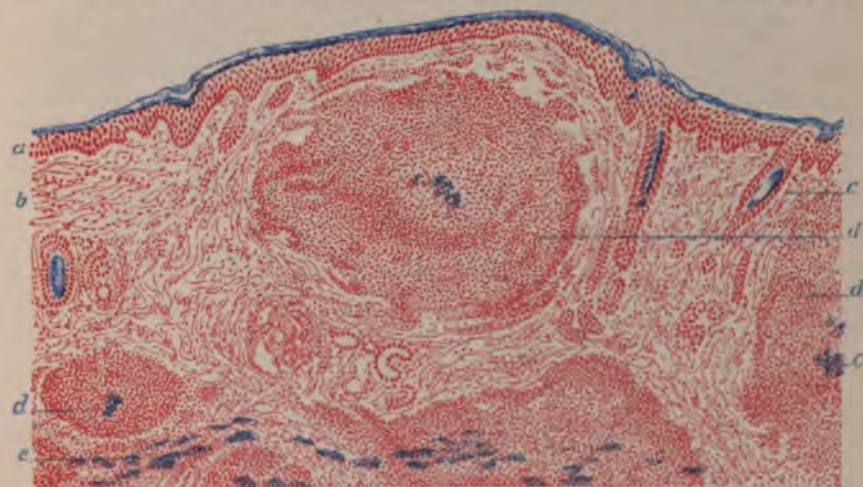


FIG. 432.—Multiple abscesses of the skin, due to staphylococci (alcohol, carmine, Gram's method). Child of three weeks. *a*, Epithelium; *b*, corium; *c*, hair-follicle; *d*, e, purulent foci with cocci.  $\times 40$ .

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§ 154. The *Staphylococcus pyogenes aureus* (Rosenbach) or *Micrococcus pyogenes* (Lehmann) consists of spherical cells occurring singly or in pairs, and by their multiplication forming grape-like clusters and swarms. The cocci are easily stained by various aniline dyes, and also by Gram's method. They are facultative anaërobes, but grow better when supplied with oxygen.

The staphylococcus thrives on all culture-media, even at ordinary room-temperatures, though better at  $37^{\circ}$  C. It forms white colonies,

which produce pigment in those parts exposed to the air and become orange-yellow. The pigment-formation is most marked on agar and potatoes. Gelatin is slowly liquefied. In the presence of grape-sugar it forms lactic acid, acetic acid, and valerianic acid. In bouillon-cultures there are produced poisons of very violent action. The *Staphylococcus pyogenes* is one of the most frequently occurring pathogenic bacteria, and is, with the *Streptococcus pyogenes*, the most common cause of **suppuration**. Both forms of cocci are therefore designated **pus-cocci**, in the narrower sense of the term. It is widely distributed throughout the external world, and has been demonstrated in milk, wash-water, and waste-water, as well as in the air of operating-rooms and sick-chambers. Increasing in the tissues of the human body (Figs. 432, 433) it causes *tissue-degenerations* and *tissue-necroses* (Fig. 434, *b*) followed by *inflammation* (Figs. 432, *d, e*; 433, *b, c*; 434, *d, e*), which is usually *purulent in character*, but not infrequently is less severe—that is, it *does not lead to tissue-suppuration*.

The *suppurations* produced by staphylococci are usually *circumscribed* (Fig. 432, 433), and show a less tendency to involve rapidly the surrounding tissue than do the suppurations caused by streptococci. In the skin they give rise in particular to the forms of inflammation known as

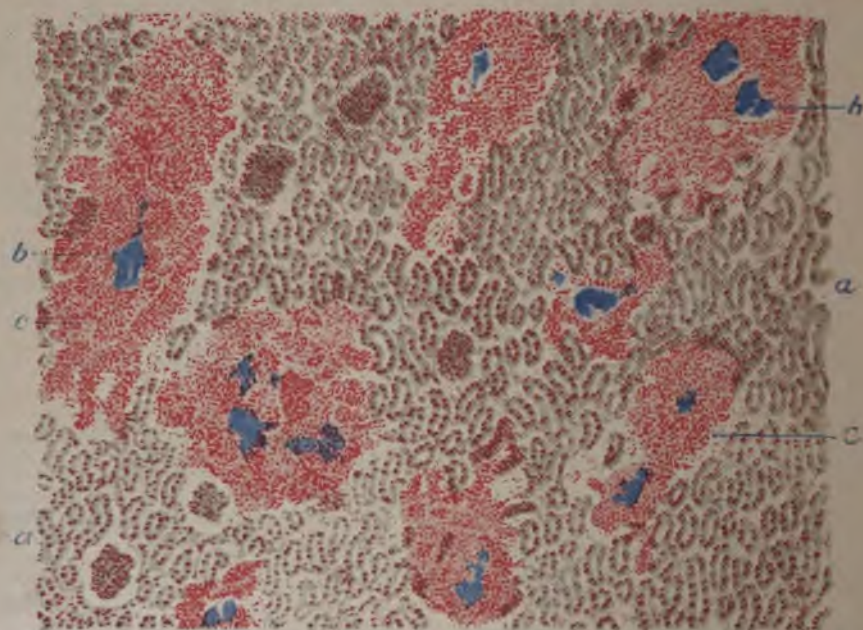


FIG. 433.—Miliary purulent nephritis, caused by staphylococci, primary focus in skin (furunculosis) (alcohol, methyl-violet, carmalum). *a*, Normal kidney tissue; *b*, collections of cocci; *c*, purulent focus.  $\times 43$ .

*acne, eczema, furuncle, and cutaneous and subcutaneous abscesses*. In the osseous system they are the most frequent cause of the hematogenous purulent diseases of the bone-marrow and periosteum known as *septic osteomyelitis* and *periostitis*. They not infrequently cause *purulent inflammations of the liver* (Fig. 434), *lungs, pleura, peritoneum, brain, meninges, muscle, myocardium, spleen, kidneys, joints, etc.*; and are often the cause of



severe, in part purulent, inflammations of the endocardium. Since the virulence of the staphylococci varies, they can also produce, in all the regions named, lighter transitory inflammations which heal with or without scar-formation.

The portal of entrance of staphylococci is often easily recognizable (especially in the case of wounds), and the same is true of the path of



FIG. 434.—Metastatic collection of staphylococcus in the liver (alcohol, Gram's, vesuvin). a, Normal liver-lobules; b, necrotic liver-lobules; c, c<sub>1</sub>, capillaries and veins filled with staphylococci; d, periportal small-celled infiltration; e, collection of small round cells, partly within, partly outside a vein, into which a central vein filled with staphylococci empties.  $\times 40$ .

the metastasis to the internal organs, whereby inflammations of the lymph-vessels (*lymphangoitis*) and of the blood-vessels (*phlebitis*, *arteritis*) make their appearance. **Cryptogenic infections** are, however, of not infrequent occurrence, so that the first recognizable localization of the infection appears in the endocardium, myocardium, or bone-marrow. The spread of staphylococci through the blood-stream leads to multiple localization with abscess formation, and this condition is designated **pyæmia**, as in the case of the similar condition caused by the streptococcus. The complication of a staphylococcus infection with severe symptoms of intoxication is also known as **septicæmia**; and the combination of a staphylococcus-pyæmia with septicæmia is also known as **septicopyæmia** (cf. § 12).

The *Staphylococcus pyogenes aureus* is also pathogenic for animals: horse, dog, cattle, goat, sheep, rabbit, guinea-pig, and mouse, particularly for

the first-named, less so for the last. In these animals it causes suppuration. The staphylococcus loses its virulence easily in cultures. The inoculation of cultures of high virulence into susceptible animals causes a gelatinous œdema.

Closely related to the *Staphylococcus pyogenes aureus* are the *Staphylococcus pyogenes albus* (Rosenbach) and the *Staphylococcus pyogenes citreus* (Passet); these forms probably represent modified varieties of the aureus. The *albus* forms whitish, the *citreus* lemon-yellow colonies. These bacteria occur in the same regions and produce the same effects as the *aureus*, but are more rare than the last named.

The *Staphylococcus pyogenes aureus* usually occurs alone in the pus-foci, but not infrequently there may be associated with it other pus-cocci or even bacilli, as, for example, the *Bacterium coli commune*, or the typhoid-bacillus.

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§ 155. The *Micrococcus Gonorrhœæ* or *Gonococcus* (Fig. 435) is a



coccus first described by Neisser in the year 1879. It is constantly present in the discharges of the purulent catarrh, known as gonorrhœa, of the male and female urethra, and female genital canal (especially of the uterus), as well as in the secretions of gonorrhœal ophthalmia. It is regarded as the cause of gonorrhœa as well as of the blennorrhœa of the eye. Besides the specific cocci, other cocci may also be present in the gonorrhœal secretions, some of them closely resembling the gonococcus; the pus-cocci may also be present.

The gonococcus may be cultivated upon coagulated human blood-serum, blood-serum gelatin, on human blood-serum-agar, on urine-agar; and forms on the surface of the nutrient medium a thin grayish-yellow layer having a smooth surface. It dies out easily, and grows only at higher temperatures. Wassermann recommends as culture-medium swines'-serum with the addition of glycerin and soda. The cell of the gonococcus contains a poison (Wassermann) which, when injected into the tissues, excites inflammation.

Animals are immune against inoculations with the gonococcus. Ef-



FIG. 435.—Gonococci in the urethral secretion from a fresh case of gonorrhœa (methylene-blue, eosin). *a*, Mucus with single cocci and diplococci; *b*, pus-cells with, *c*, pus-cells without diplococci.  $\times 700$ .



FIG. 436.—Urethritis gonorrhœica. Cross-section through the mucous membrane which had been thrown into folds (Müller's fluid, hematoxylin, eosin). *a*, Normal connective tissue; *b*, *c*, inflammatory, infiltrated, proliferating connective tissue of the mucosa; *d*, infiltrated and desquamating epithelium; *e*, desquamated epithelial cells and pus-corpuscles.  $\times 100$ .

forts were made by Boeckhart and Bumm to inoculate human beings with artificially cultivated gonococci, and they succeeded in obtaining in this way a purulent catarrh of the inoculated mucous membrane. The experiments of Bumm, in particular, appear to have given in the case of two women a positive result.

In the purulent secretion of the mucous membrane infected with gon-

orrhœa the coccus usually forms clumps, and for the greater part appears in the form of diplococci, the opposing surfaces of which are flattened (Fig. 435); but occurs also in part free (*a*), and in part inclosed within cells (*b*). It stains easily with aniline dyes, but is decolorized by Gram's method.

The gonococcus penetrates into the epithelial layer of the affected mucous membrane, and lies partly between and partly in the epithelial cells, and in leucocytes. Only the uppermost layers of the connective tissue are infiltrated. The infiltration is most marked in the case of cylindrical epithelium, while in the regions covered by squamous epithelium (fossa navicularis, vagina) the cocci lie more superficially. They cause inflammations which bear the character of *purulent catarrhs*, and are associated with a cellular infiltration of the tissue of the mucosa (Fig. 436, *b*, *c*, *d*) and with epithelial desquamation. The male and female urethra and the adjoining parts of the genital glands and ducts, and the urinary passages form the chief seats of localization. According to Scholz there occurs, after a three-weeks' duration of the disease in the male urethra, a metaplasia of cylindrical cells into stratified squamous cells, and the secretion decreases after this time. To what extent the deeper inflammations so frequently accompanying or following gonorrhœa (peri-urethral abscesses, prostatitis, epididymitis, vesiculitis, cystitis, inflammation of the ducts of Bartholin's glands, salpingitis, ovaritis, pelvic peritonitis, arthritis, etc.) are to be referred to the spread of the gonococcus or to what extent to secondary infections by the pus-cocci is yet a disputed question. According to the investigations made up to the present time there can be no doubt that the gonococcus may become widely spread over the surface of the mucous membranes. It has been many times demonstrated in inflamed tubes, ovaries, joints, cardiac valves, tendon-sheaths, bursæ, in peri- and parametric foci of inflammation, and in peri-urethral abscesses. In these cases it has been regarded as the cause of the inflammation, yet the processes which lead to suppuration and even the metastases in distant organs appear to be more frequently dependent upon the presence of pus-cocci.

Gonorrhœal infection is at the beginning an acute process, but may become chronic, and is cured only with great difficulty; since the gonococci can maintain themselves here and there in the urethra, tubes, etc., for years, and continue to cause inflammation.

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§ 156. Cocci have been demonstrated with certainty as the cause of disease in animals in the case of a large number of infectious diseases, and are regarded with probability as the cause in the case of others. As has already been stated, the *Streptococcus pyogenes*, the *Diplococcus pneumoniae*, and the *Micrococcus pyogenes aureus* are also pathogenic for different animals, and the last named in particular often causes spontaneous—not caused by inoculation—suppurative inflammations in animals. Moreover, diseases have also been produced experimentally in animals by different cocci which were not pathogenic for man. Further, in many spontaneous diseases of animals cocci have been demonstrated, which are probably to be regarded as the cause.

(1) According to Schütz ("Der Streptococcus der Drüse der Pferde," Arch. f. wiss. u. prakt. Thierheilk., xiv., 1888; Zeit. f. Hygiene, iii.), Sand and Jensen ("Die Aetiologie der Drüse," Deutsch. Zeit. f. Thiermed., xiii.), and Poels ("Die Mikokokken der Drüse der Pferde," Fortschr. d. Med., vi.) the strangles of horses is an infectious disease, in which the mucous membrane of the upper respiratory tract is the seat of a mucopurulent inflammation, in which, moreover, the lymph-glands pertaining to the region become swollen and in part suppurate; and is caused by a chain-forming coccus, which can be cultivated, and, when inoculated into horses (Schütz) again produces the disease.

(2) According to Schütz ("Die Ursachen der Brustseuche des Pferdes," Arch. f. wissensch. u. prakt. Thierheilk., 1887; Virch. Arch., 107 Bd., 1887) the epidemic lung-disease of horses (infectious pneumonia) is caused by an oval coccus, which forms pairs and chains, and is not identical with the *Diplococcus pneumoniae* (Fränkel) or the *Bacillus pneumoniae* (Friedländer), and therefore not identical with the bacterium described by Proncinto (Arch. ital. de biol., vii., 1886) as occurring in the pneumonia of horses, and held by him to be identical with the *Diplococcus pneumoniae*.

(3) According to Semmer and Archangelski (Centralbl. f. d. med. Wiss., 1883; Deutsch. Zeit. f. Thiermed., xi.) the microparasite of "Rinderpest" is a micrococcus. According to Metschnikoff and Gamaleia (Centralbl. f. Bakt., i., p. 633) it is a bacillus. The disease is characterized anatomically by an inflammation of the intestinal tract, in part of a croupous or diphtheritic character, as well as by swelling and at times necrosis of Peyer's patches.

(4) According to Poels and Nolen (Fortsch. der Med., iv., 1886) monococci and diplococci, which in part possess a gelatinous capsule, are found constantly in the lungs and in the pleural exudate, in the contagious pleuropneumonia of cattle. On gelatin and agar-

agar they form chiefly white colonies which later become cream-colored. Pure cultures injected into the lungs of rabbits, guinea-pigs, dogs, and cattle, give rise to pneumonic changes. (Literature: *Pasteur, Recueil de méd. vét.*, 1883; *Cornil et Babes, Arch. de phys.*, 1883; *Süssdorf, Deut. Zeitschr. f. Thiermed.*, 1879).

(5) In the udder-inflammations of the domestic animals, which occur sometimes sporadically, sometimes epidemically, different *micrococci* and *streptococci* have been described, and designated by various names (*Hess and Bergeaud, "Contag. Euterentzündung, gelber Galt genannt," Schweiz. Arch. f. Thierheilk.*, 30 Bd., 1888; *Frank, "Euterentzündungen," Dtsch. Zeit. f. Thiermed.*, ii., 1876; *Kitt, "Euterentzündung," Lehrb. d. path. anat. Diagnostik,* Stuttgart, 1894; *Jensen, "Mastitis," Ergebn. d. allg. Path.*, iv., 1899).

(6) According to *Johne* ("Seuchenart. Cerebrospinalmeningitis d. Pferde," *Dtsch. Zeitschr. f. Thiermed.*, xxii., 1887) the cerebrospinal meningitis, which occurs epidemically in horses, is caused by the *Diplococcus intracellularis* (*Weichselbaum*, § 158).

(7) *Babes* found in the hæmoglobinuria of cattle, which occurs as an epidemic disease in Roumania, a coccus similar to the gonococcus, which he regards as the cause of the disease ("Sur l'hémoglobinurie bactérienne du bœuf," *Compt. rend. de l'Acad. des Sciences de Paris*, cvii., 1888; *Virch. Arch.*, 115 Bd.; *Annal. de l'Institut de pathol. à Bucarest*, 1890).

(8) According to *Semmer, Friedberger, and Mathis* (*Centralbl. f. Bakt.*, iii., p. 343) the distemper of dogs is also caused by a coccus.

(9) The foot-and-mouth disease of cattle, according to *Klein* (*Cbl. f. d. med. Wiss.*, 1886) is caused by a streptococcus. Several years ago *Schottelius* ("Ueber einen bakteriologischen Befund bei Maul- und Klauenseuche," *Cbl. f. Bakt.*, xi., 1892) and *Kurth* ("Bakt. Untersuch. bei Maul- und Klauenseuche," *Arb. a. d. Reichsgesundheitsamt*, viii., 1893), and others also found cocci in the organs of animals affected with foot-and-mouth disease; but the bacteria described do not correspond with one another, and their pathogenic significance is doubtful (*Johne, Dtsch. Zeitschr. f. Thiermed.*, xix., 1893; *Löffler and Frösch, Cbl. f. Bakt.*, xxii., p. 257, 1897).

(10) According to *Rivolta* and *Johne* (*Dtsch. Zeitschr. f. Thiermed.*, xii.; "Bericht über das Veterinärwesen im Königr. Sachsen f. d. J. 1885") and *Rube* (*Dtsch. Zeitschr. f. Thiermed.*, xii.) there occurs in horses a peculiar tumor-like growth of connective tissue, designated by *Johne* as *mycofibroma* or *mycodesmoid*, which is caused by a micrococcus that grows in animal tissues in round or grape-like colonies which quickly become surrounded by a hyaline capsule, and are therefore to be reckoned as *ascococci* (*Micrococcus ascoformans*). *Bollinger* designates the coccus as *Botryomyces*, *Rube* as *Micrococcus botryogenes*, *Kitt* as *Botryococcus ascoformans*. The growths consist of connective tissue, resembling those of actinomycosis, and inclose small suppurating foci of granulation tissue which contain the fungi. They appear to develop most frequently in the spermatic cord after castration, but occur also on other parts of the body (*Kitt, "Der Micrococcus ascoformans und das Mycofibrom des Pferdes," Cbl. f. Bakt.*, iii., 1888; *Schneidmühl, "Botryomycosis," Cbl. f. Bakt.*, xxiv., 1898 [Lit.]).

(11) According to *Eberth* (*Virch. Arch.*, 80 Bd.) and *M. Wolff* (*Virch. Arch.*, 92 Bd.) many of the gray parrots brought to Europe (*Psittacus erithacus*) die of a streptococcus mycosis. The micrococci are found in almost all the organs, but especially in the capillaries of the liver and their neighborhood, where they cause necrosis of the liver-cells, but no suppuration.

(12) According to *Eberth* (*Virch. Arch.*, 100 Bd.) a part of the pseudotuberculous processes occurring in guinea-pigs represent a chronic suppuration caused by a coccus, and sometimes lead to metastases in other organs.

## 2. THE BACILLI AND THE POLYMORPHOUS BACTERIA, AND THE PATHOLOGICAL PROCESSES PRODUCED BY THEM.

### (a) General Considerations Regarding Bacilli and the Polymorphous Bacteria.

§ 157. Under the designation **bacilli** or **bacillaceæ** (*A. Fischer*), or **Bacteriaceæ** (*Zopf*) may be classed all those bacteria which occur in the form of straight rods or rods which are slightly bent in one plane. By many authors (*Cohn, Hüppe, Lehmann*) the bacillaceæ are divided into two groups: **bacterium** and **bacillus**, the latter being characterized by the production of endogenous spores, while spore-formation is lacking in the former.



The **bacilli** multiply by division. The rods grow in length, and divide into approximately equal parts through the formation of a transverse partition-wall. If the division of one of the elongating bacilli is delayed, or if the separation of the individual rods from one another is not distinctly recognizable, there arise long, unbranched rods or threads (Fig. 438, *b*). If the divided rods remain attached to each other, there are formed chains of rods (Figs. 437, *c*; 438, *c*). In many forms of bacilli the ends of the individual rods are blunt, in others rounded or pointed.

In many bacilli resting as well as swarming stages are observed. Flagella serve as the organs of motion (Fig. 437, *b*); they are situated sometimes at the ends, sometimes on the sides of the rods, and may occur in large numbers. In many bacilli an endogenous **spore-formation** is observed (Figs. 437, *d, e*; 438, *d*), the spores lying sometimes in the middle, sometimes at one end of the cell. Not infrequently the spores appear within jointed threads. The germination of spores results in the formation of new rods (Figs. 437, *f*<sup>1-3</sup>, 438 *e*<sup>1-3</sup>).

During spore-formation the rods usually do not change their shape

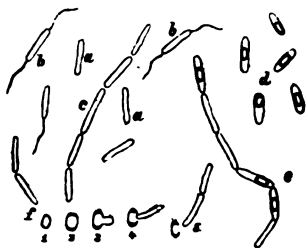


FIG. 437.

FIG. 437.—*Bacillus subtilis* in various stages of development (Prazmowski). *a*, Single rods; *b*, rods with flagella; *c*, chain of rods; *d*, single cells with spores; *e*, chain of rods with spores; *f*<sup>1-3</sup>, germination of a spore.  $\times 800$ .

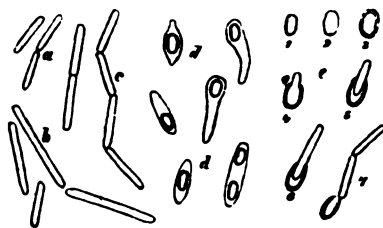


FIG. 438.

FIG. 438.—*Clostridium butyricum* (Prazmowski). *a*, Short rods; *b*, long rods; *c*, chain of rods; *d*, cells with spores; *e*<sup>1-3</sup>, germination of a spore.  $\times 800$ .

to any marked extent. In other cases they assume a spindle-, club-, or pear-shape (Fig. 438, *d*), and these changes have been taken as the basis for the establishment of an especial group, *clostridium*. On the other hand, numerous authors class these forms with the bacilli.

In the non-pathogenic bacilli spore-formation and spore-germination have been more carefully studied, especially in the case of *Bacillus subtilis* and *Bacillus amylobacter*; and these bacilli offer good examples of the processes which come under consideration in this connection.

**Bacillus subtilis** is a fission-fungus whose spores are widely distributed in the ground, hay (hay-bacillus), and in the air. When cultivated upon potato or upon the dung of herbivorous animals, it forms whitish-yellow colonies; upon liquids it forms thin and thick pellicles. It requires oxygen for its development.

The fully developed rods (Fig. 437, *a*) are  $6\ \mu$  long. The snake-like motions occurring at times are produced by means of numerous lateral and terminal flagella. Through the growth of the rods undivided threads are formed which after division form chains of rods. The separate cells may develop in their interior glistening, sharply contoured spores (*d, e*), which lie either in the middle or nearer to one end of the cell. Later

the cells in which the spores have been formed die. During germination the spores become pale (Fig. 437 'c'), lose their glistening appearance and their sharp contour. A shadow then appears at each pole, while the spore begins a tremulous motion. After a time the contents of the spore project from the membrane of the spore in the form of a germinal utricle, which later becomes elongated, divides, and produces swarming rods. The empty spore membrane may remain preserved for some time after the exit of the young cell.

The *Bacillus butyricus* (*Bacillus amylobacter* of Van Tieghem, *Vibrio butyrique* of Pasteur, *Clostridium butyricum* of Prazmowski) consists of rods of 3 to 10  $\mu$  in length, and also forms threads and chains of rods. During spore-formation the cells become spindle-, club-, or tadpole-shaped (Fig. 438, d), and then produce one to two glistening spores. In germination, after the absorption of the spore-membrane a germinal utricle appears at one of the two poles (Fig. 438, e'-'); this becomes elongated, and produces new rods by segmentation.

The *Bacillus butyricus* does not need oxygen for its development; it produces butyric-acid fermentation with evolution of carbonic acid, in solutions of starch, dextrin, sugar or glycerin. In media containing starch, glycerin, or cellulose the bacilli are colored blue with iodine.

The polymorphous bacteria are distinguished from the bacilli by the fact that they form, besides rods, also long threads, in part with false or true branching; and in individual cases a basal non-proliferating end and an apical proliferating end may be distinguished. In this category may be placed the fungi designated *Streptothrix*, *Cladothrix*, *Beggiatoa*, and *Crenothrix*. They are here placed with the bacilli, because, on the one hand, their botanical position is not definitely determined, while, on the other, in so far as they are pathogenic, they conform most closely to the bacilli in their biological properties (cf. diphtheria-bacilli, tubercle-bacilli, and actinomyces).

The **saprophytic bacilli** produce many forms of fermentation by their growth in nutrient fluids; many also form pigments.

*Bacillus prodigiosus* grows upon potatoes and bread, as well as upon agar-agar, and upon nutrient gelatin, liquefying the latter. It forms a red coloring matter which is soluble in alcohol. The pigment is formed only in the presence of oxygen; in the growth in milk the coloring-matter is contained in the fat-droplets. The bacilli themselves are always colorless.

*Bacillus fluorescens liquefaciens* forms whitish cultures in gelatin, in the neighborhood of which the gelatin is liquefied while in the remote surrounding portions it gradually takes on a greenish-yellow fluorescence.

*Bacillus cyanogenes* (Neelsen, Hueppe), when cultivated in sterilized milk, causes a slate-gray color that changes through the addition of acid to an intense blue. In unsterilized milk, in which lactic-acid bacteria develop at the same time, a blue color appears without the addition of acid. On potatoes it forms yellowish, slimy cultures, in the neighborhood of which the substance of the potato is colored grayish-blue (Flügge).

*Bacillus acidi lactici* ferments milk-sugar into lactic acid and coagulates casein. In gelatin it produces white cultures.

*Bacillus caucasicus* (*Dispora caucasica*) forms one of the constituents of the fungus-conglomerate known as kephir-ferment, which is used by the inhabitants of the Caucasus in the preparation, from cow's milk, of the alcoholic drink called kephir. The kephir-ferment consists of small

granules containing yeast-cells and bacilli. The latter at times show movements, and form a round spore at the end of each rod. As the result of their growth in milk the milk-sugar is probably converted into glucose, while the yeast-cells produce alcoholic fermentation. According to Hueppe, the kephir granules contain still other bacteria which peptonize casein.

As *Proteus vulgaris*, Hauser has described a bacillus (*Bacterium vulgare* of Lehmann) which is very frequently present in decomposing animal substances and in human cadavers, and in gangrenous ulcers, and causes putrid decomposition. It forms rods of varying length, and produces, when cultivated in meat (Carbone), æthylendiamin, gadinin, and trimethylamin, of which the first two bases are poisonous for animals. According to observations by numerous authors, it is not infrequently found in *human tissues*, chiefly in association with other bacteria, streptococci, pneumococci, diphtheria-bacilli; and by its presence aggravates the course of the infection and causes *putrid decomposition* of the pus and the necrotic tissue. In rare cases it may *alone*, without the association of other bacteria, *cause inflammations*, particularly of the urinary bladder (*cystitis*). Several cases of *hæmorrhagic enteritis* have also been described, in which a form of proteus was regarded as the causal agent. Further, proteus has also been found in inflammations of the female genital tract, serous membranes, and liver (infectious icterus), and has been considered to be the cause of the given inflammation. *Proteus* must therefore be classed with the *parasitic or pathogenic bacteria*. Its pathogenic activity rests chiefly upon the formation of poisonous substances. (Literature given by Meyerhof, *l. c.*).

*Bacillus aceticus* (*Mycoderma aceti*) is a bacillus which converts the alcohol of fermented beverages into acetic acid.

*Bacillus pyocyaneus* occurs occasionally in bandages upon suppurating wounds and causes a greenish-blue discoloration of the same. The bacilli are small and slender. The cultures show different forms of growth. Gelatin is liquefied and turned green. The coloring-matter called *pyocyanin* is soluble in chloroform and crystallizes from the solution in long blue needles. The bacillus is pathogenic for rabbits, guinea-pigs, pigeons, and frogs; inoculations give rise partly to local ulcerations, partly to general infections. According to Kossel, Kraunhals, Neumann, and others it may also be *pathogenic for man during the age of childhood*, and from suppurating wounds or mucous membranes (middle ear) it may cause septicæmia with splenic tumor and enteritis. Blum observed a pyocyanic endocarditis in a nursing infant.

The *pathogenic bacilli* and *polymorphous bacteria* cause partly acute, and partly chronic affections, the former terminating either in death or in healing after the destruction of the bacteria. It also happens in the acute diseases that the bacteria may remain in the body for a long time. The chronic affections are characterized by the persistence and multiplication of the bacteria within the body, so that the disease assumes a progressive character, and sometimes slowly, sometimes rapidly, new regions are in turn invaded by the bacteria and suffer pathological changes.

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*(b) The Pathogenic Bacilli and Polymorphous Bacteria.*

§ 158. The **Bacillus anthracis** (*Bacteridie du charbon*) is the cause of anthrax, a disease occurring chiefly in cattle and sheep, and occasionally transmitted to man. It is a fission-fungus which, when inoculated into a susceptible animal, may increase within the tissues as well as in the blood.

The **anthrax-bacilli** (Fig. 439) are 3 to 10  $\mu$  long and 1 to 1.5  $\mu$  broad. In the blood of animals affected with anthrax they occur either singly or in thread-like jointed bands of two to ten rods, whose ends are for the greater part sharply cut across (Figs. 439, 440), more rarely slightly concave or even slightly convex (Johns). According to Pianese, Serafini, Günther, and Johns they possess a gelatinous capsule which is best brought out by the staining of dried preparations with methylene-blue. They can be cultivated upon blood-serum-gelatin, in bouillon, upon



slices of potatoes and turnips, in infusions of peas and mashed grain of various kinds, etc., in the presence of oxygen (according to Klett also in an atmosphere of nitrogen); and grow most rapidly at a temperature of from 30° to 40° C. At temperatures below 15° and above 43° C. development is impossible.

Under suitable conditions of growth the rods increase in length, and may within a few hours form non-encapsulated threads of considerable

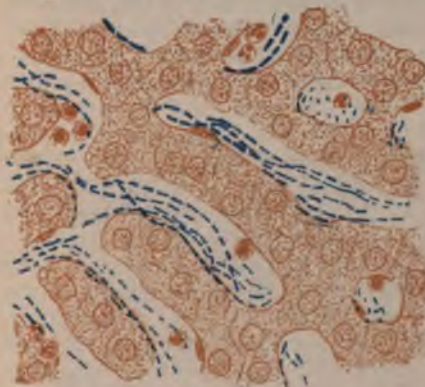


FIG. 439.—Section from a liver whose capillaries contain numerous anthrax-bacilli and scattered leucocytes (alc.hol, gentian-violet, vesuvium).  $\times 300$ .

length. These consist of short segments whose outlines may be made visible by treatment with iodine or by stains (Fig. 440). Ten hours later the clear contents of the threads become granular, and at regular intervals there become apparent dull-shining bodies, which after a few hours enlarge into strongly refractive spores (Fig. 440). Later the threads disintegrate and the spores become free.

According to Brefeld, Prazmowski, Klein, and others, the spore consist of a protoplasmic centre, which is inclosed by a double membrane, the exosporium and the endosporium. During germination the former is ruptured, the latter

becomes the membrane of the embryo. The liberated embryo multiplies by division.

Swarming movements are not seen throughout the entire period of development; the bacilli are always motionless.

The bacilli of anthrax are easily killed by high temperatures, drying, and through the decomposition of the nutrient fluid. The spores on the other hand are very resistant, and are therefore usually the medium of the spread of the disease.

The colonies upon gelatin show a wavy, irregularly shaped margin, and consist of many interlacing strands of threads, which later grow out of the culture in all directions. The gelatin is liquefied immediately about the culture. On potato the bacillus forms grayish-white, slightly granular colonies having a sharply outlined border. On blood-serum it forms a white coating.

Stab-cultures in gelatin are white and during the process of growth they radiate at right angles from the line of inoculation out into the gelatin, particularly near the surface. After liquefaction of the gelatin they sink to the bottom.

If the bacilli or the spores gain entrance into the blood, they increase and form rods as described above, which stain with different aniline dyes, and also by Gram's method. Sections of hardened tissue show that they are present in large numbers in the capillaries (Fig. 439), particularly in the spleen, liver, lungs, and kidneys. The neighboring parenchyma for the greater part appears unchanged; still the local proliferation of the bacilli can also cause tissue-degeneration and necrosis. If

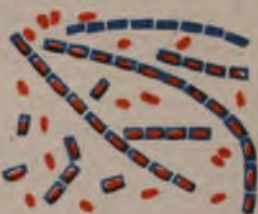


FIG. 440.—Spore-containing anthrax-bacilli and free spores. Cover-glass preparation from a culture of the bacilli grown in the incubator upon potato, and stained with fuchsin and methylene-blue.  $\times 800$ .

an infection of the blood takes place during pregnancy the infection may pass over to the foetus.

Anthrax-bacilli or their spores may gain entrance into the skin of man, an event which is particularly likely to happen in the case of individuals who butcher, or shear, or prepare the skins of animals affected with anthrax; or occasionally the infection may be transmitted by means of the sting of a fly which has taken up blood from an animal infected with anthrax. There develops at the place of infection a somewhat elevated pustule (Fig. 441) from 6 mm. to several centimetres in diameter, having an arched or flattened surface, and of a red or at times a more yellowish color. This is often after a time covered with vesicles, or after



FIG. 441.—Section from an anthrax-pustule ten days old, taken from the arm of a man (alcohol, Gram's method, vesuvin). *a*, Epidermis; *b*, corium; *c*, papillary body oedematously swollen and infiltrated with exudate and bacilli; *d*, outer layer of corium, infiltrated with cells; *d*<sub>1</sub>, the same, containing also bacilli; *e*, deep layers of the corium infiltrated by cords of cells; *f*, dermal tissue infiltrated with bacilli and cells; *g*, bloody exudate containing bacilli, lying upon the surface; *h*, hair-follicle; *i*, sweat-gland.  $\times 33$ .

the loss of the epithelium becomes moist; so that through the drying of the oozing, often bloody exudate, a scab is formed (Fig. 441, *g*).

The centre may become depressed through the formation of a central scab, so that the edges form a wall about the latter. The neighborhood of the pustule is sometimes but slightly changed, at other times reddened and swollen, and may be set with small yellow or bluish-red vesicles. If the process remains local, the gangrenous pustule may be thrown off. Infection of the blood is fatal. In rare cases the infection from the beginning may show itself as an extensive, intense, oedematous swelling of the tissue without the formation of a circumscribed elevation.

In the region of a fully developed anthrax-pustule (Fig. 441), the corium (*d*, *d*<sub>1</sub>) and the papillary body (*c*) are infiltrated with a serocellular



exudate as well as by bacilli. The bacilli lie particularly in the outer portions of the corium (*d*) and in the papillary body (*e*), but may also penetrate into the deeper layers of the corium (*f*). In the neighborhood of the papillary body (*e*) the exudate is sanguineous. Vesicles filled with bloody fluid result if the exudate extends up to the epithelial covering, and if the deeper portions of the latter become liquefied, thereby permitting the lifting-up of the superficial layers by the exuded fluid. If the upper layers of the skin are also lost, the bloody fluid containing the bacilli (*g*) appears upon the surface.

The cellular infiltration has its seat chiefly in the corium (*d*, *d*, *e*), and the impression is obtained as if the great massing of cells formed a certain protection against the further spread of the bacilli. The cells which collect belong for the greater part to the polynuclear leucocytes (Fig. 442). The bacilli lie sometimes in, sometimes between the cells.

If an infection with anthrax-spores takes place in the intestinal canal, an event which occurs most frequently in the small intestine, less often in the stomach and large intestine, there develop dark-red or brownish-red hæmorrhagic foci, the size of a lentil or bean or larger, with a grayish-yellow or greenish-yellow, discolored slough in the centre. In other cases the crests of the folds of the mucosa are swollen and hæmorrhagic, and show evidences of sloughing in the most prominent parts. The mucosa and submucosa are infiltrated with blood in the region of the foci; the surrounding tissues are œdematous and hyperæmic. Bacilli are found in the tissues both in and about the foci, particularly in the blood- and lymph-vessels, and they may also be demonstrated in the neighboring lymph-glands.

According to observations by Eppinger and Paltauf, primary lung infection may also occur in man as the result of the inhalation of anthrax-spores, proving fatal in from two to seven days. Individuals who have to handle the hair of animals that have died of anthrax are especially exposed to infection; and the disease known as *rag-sorter's disease*, which occurs in men and women employed in the sorting of rags in paper-factories, is in a part of the cases nothing more than an anthrax infection. The spores taken into the lungs in the respired air develop in the bronchi and alveoli, in the lymph-spaces of the lungs and pleura and in the bronchial glands, and penetrate also into the vessels. Their growth causes inflammatory processes in the lungs, as well as serous hæmorrhagic exudations into the pleural cavity and the mediastinal tissue, and swellings of the lymph-glands. It may also lead to the production of necrotic foci in the lungs, and in the bronchial and tracheal mucosa.

Mice, rabbits, sheep, horses, and sparrows are very susceptible to anthrax; white rats, dogs, and Algerian sheep are less susceptible or immune. Cattle are easily infected through the taking in of the spores from the alimentary canal, but are less susceptible to inoculation. Formation of spores does not take place in the tissues and in the blood.

A marked attenuation of anthrax-bacilli may be produced by keeping the bacilli for ten minutes at a temperature of 55° C. (*Toussaint*) or for fifteen minutes at 52° C., or for twenty minutes at 50° C. (*Chauveau*), or further through the influence of oxygen under high pressure (*Chauveau*). The bacilli attenuated by exposure for a short time

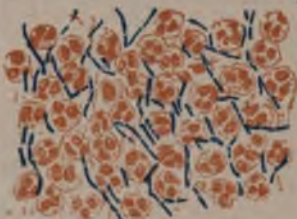


FIG. 442.—Portion of the anthrax pustule from the arm (Fig. 441), containing bacilli.  $\times 350$ .

to high temperatures quickly regain their virulence; those attenuated at lower temperatures remain weakened for many generations.

The addition of carbolic acid to the nutrient fluid in a proportion of 1:600 permits the further development of anthrax-bacilli, but destroys their virulence within twenty-nine days (*Chamberland, Roux*). Likewise, an attenuation may be produced by the addition of potassium bichromate (1:2,000-1:5,000). The addition of carbolic acid up to 1:800 hinders at the same time the formation of spores.

Through cultivation of the bacilli at 42-43° C. (*Toussaint, Pasteur, Koch*) their virulence may be so weakened that they no longer kill first sheep, then rabbits and guinea-pigs, and finally mice. If the temperature is kept in the neighborhood of 43° C. this result may be obtained in six days; at 42° C. it may require about thirty days to decrease the virulence to this extent (*Koch*). By first inoculating with bacilli which kill mice but are harmless for guinea-pigs, and afterward inoculating with bacilli which kill guinea-pigs but not strong rabbits, an immunity against anthrax may be obtained in sheep and cattle but not in the case of mice, guinea-pigs, and rabbits. Such protective inoculations are, however, not of practical value, since, in order to protect against natural infection with spores from the intestinal canal, such virulent inoculation-material must be used that a large per cent. of sheep (ten to fifteen per cent.) die from the inoculations. Further, the protection afforded by the inoculations is of very short duration, and the inoculation must be repeated within a year's time.

According to observations by *Roux* and *Chamberland* anthrax bacilli which are cultivated in bouillon to which a small amount of potassium bichromate (1:2,000) or carbolic acid (1 to 2:1,000) has been added, permanently lose their power of spore-formation while retaining their virulence.

According to *Koch*, anthrax-bacilli may be cultivated in the presence of abundance of water upon potatoes and in an alkaline or neutral hay-infusion, cold infusions of pea-straw, on mashed barley and mashed wheat, in the juice of turnips, on maize, leguminous seeds, and numerous dead plants. Consequently they are able to grow and develop outside of the animal body—for example, in marshy regions and on river-banks (*R. Koch*). The entrance into the animal body is to be regarded as an accidental excursion of ectogenic bacilli. According to *Soyka* the development of spores takes place very quickly in a moist medium containing the necessary nutrient material at temperatures above 15° C. According to *Kitt* the dung of cattle forms a nutrient substratum for the bacilli.

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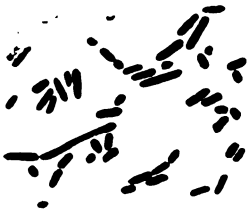


FIG. 443.

FIG. 443.—Typhoid-bacilli from a pure culture. Streak-preparation (methylene-blue).  $\times 1,000$ .

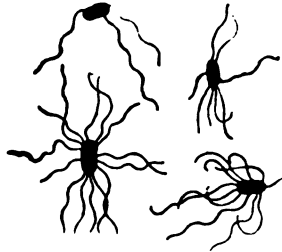


FIG. 444.

FIG. 444.—Typhoid-bacilli with flagella. (After Bunge.)  $\times 1,200$ .

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For literature concerning the intra-uterine transmission of the bacillus to the fœtus, see § 150.

§ 159. The **Bacillus typhi abdominalis** (Fig. 443), or the *Bacterium typhi*, is a fission-fungus which occurs chiefly in the form of plump rods 2 to 3  $\mu$  long, having rounded ends, and in cultures growing also in pseudothreads. It is regarded as the cause of *typhoid fever*. When examined alive in cultures it shows *lively independent movements* which are accomplished by means of flagella (Fig. 444) attached to the *sides* of the rods as well as to their *ends*. The flagella may be demonstrated by proper staining-methods. The bacillus was first observed in the intestinal lesions by Eberth and Koch, and described by them; and was later isolated in pure cultures by Gaffky. A. Pfeiffer demonstrated its presence in the dejecta of typhoid patients, and his findings have been confirmed from many sides. According to Seitz, Hueppe, Neumann, and others it may also be present in the urine of typhoid patients.

It stains well in cover-glass preparations, with gentian-violet, alkaline methylene-blue, and Bismarck brown. It is decolorized by Gram's

method. It is difficult to demonstrate it in sections of hardened tissues, since the cell-nuclei also take the stain, and because the bacilli are not uniformly distributed but are usually found lying in the tissue in clumps.

The bacillus may be cultivated upon nutrient gelatin, agar-agar, and blood-serum, also in milk, and upon potato. Upon the last named it forms a coating which can be scarcely recognized by the naked eye; but when the surface is touched with a platinum wire it becomes apparent that it is covered with a pellicle, which on microscopic examination is shown to consist of bacilli.

On gelatin and agar-agar the bacilli form grayish-white, irregularly shaped, flat growths. *Gelatin is not liquefied.* Milk in which the bacilli are grown is not changed externally.

The cultures thrive at room-temperature as well as at body-temperature. Potato-cultures made in the usual manner, when kept between 30° and 42° C., produce rods which have glistening bodies in their poles. Gaffky regarded these as spores, and the majority of authors formerly accepted this view. According to Buchner and Pfuhl, however, these granules at the poles are degeneration phenomena, which occur particularly when acid is present in the culture medium. The polar granules represent condensed protoplasm, and therefore stain in fresh preparations more quickly with the aniline dyes than do the other parts of the cell. The clear, colorless spots which are seen at the ends of the rods in dried and stained bacilli have been held to be identical with the polar granules and therefore regarded as spores; but are due, according to Buchner, to hollow spaces formed at the ends of the rods as the result of the retraction of the protoplasmic tube following the death and drying of the bacilli. Spore-formation has, therefore, not yet been demonstrated.

In moist earth (Grancher, Deschamps), in pure and impure water, typhoid bacilli may remain alive for weeks. In artificial Seltzer water they do not die out for a longer period (Hochstetter). In privy vaults and faecal masses, or in earth saturated with faecal matter (Finkler, Uffelmann, Karlinski) they may under certain conditions live for weeks and months.

Inoculations of the bacilli in the case of the animals ordinarily used for experiment do not produce a disease corresponding to typhoid fever in man. On the other hand, the experiments of Sirotinin, Beumer, Peiper, and others have shown that the typhoid-bacilli produce active toxins and toxalbumins (Brieger) which in large doses kill the animals, causing hyperæmia and swelling of the intestinal follicles, mesenteric glands, and the spleen. Cultures injected into the tissues cause a local inflammation of greater or less intensity.

The bacilli or their spores gain entrance into the *human organism* through the drinking-water and food; though infection through the lungs is not to be excluded. According to the results of anatomical investigations, they develop particularly in the intestinal wall, in the *solitary and agminated follicles of the small and large intestines*, as well as in the *mesenteric lymph-glands* and in the *spleen*. In the first-named place they cause an *inflammatory infiltration of the mucosa and submucosa* (Fig. 445, *a*, *b*), which is extraordinarily rich in cells, and appears in the form of flat or somewhat rounded elevations projecting above the inner surface of the intestines. An exudation of fibrin in the form of threads may take place both on the free surface and in the deeper layers. Occasionally cellular inflammatory foci of limited extent also occur in the muscularis (*c*, *d*) and the serosa (*e*). A part of the infiltrated tissue usually sloughs and

is then cast off, so that ulcers are formed. In other parts the infiltration may be absorbed and the swelling disappear.

The *swelling of the lymph-glands*, which is likewise caused by an accumulation of cells and fluid, and occasionally of fibrin, ends either in healing through the absorption of the infiltrate or may also lead to a partial necrosis of tissue. In the *spleen* the pulp in particular swells, while its vessels are greatly dilated with blood, and the parenchyma later becomes crowded full of cells and fluid.

According to recent investigations the *bacilli are usually distributed throughout other parts of the body*, and it is probable that the inflammatory exudations in the lungs occurring at times during the course of typhoid fever are due in part to an increase of the bacilli within the lungs. It should always be borne in mind that aspiration-pneumonias are of very frequent occurrence in the lungs of typhoid patients, and also that *sec-*



FIG. 445.—Typhoid fever. Section through the edge of a swollen Peyer's patch (alcohol, Bismarck brown). *a*, Mucosa; *b*, submucosa; *c*, muscularis interna; *d*, muscularis externa; *e*, serosa; *a*<sub>1</sub>, *b*<sub>1</sub>, *c*<sub>1</sub>, *d*<sub>1</sub>, *e*<sub>1</sub>, different layers of the intestinal wall showing infiltration; *f*, sections of glands of Lieberkühn; *g*, follicle.  $\times 15$ .

*ondary infections* (cocci) may take place from the ulcers and may give rise to metastatic inflammations in different tissues. The swellings of the mucosa and submucosa and of the perichondrial tissue, which often occur in the palate, throat, and larynx, are in part the result of the specific infection, and in part of secondary disease. Moreover, typhoid bacilli have been demonstrated in the liver, gall-bladder, in the rose-spots of the skin, in the kidneys, central nervous system, testicles, in pleuritic and peritoneal fluids, in the periosteum, bone-marrow, etc., in part by means of the microscope and in part by means of cultivation. In all of these regions they may cause degeneration and inflammation, and give rise to suppuration, so that the inflammations occurring during the course of typhoid fever owe their origin sometimes to the dissemination and localization of the typhoid-bacilli, and sometimes to secondary or mixed infections.

Neuhauss demonstrated the presence of typhoid-bacilli in the spleen of a four-months fœtus, the mother aborting during an attack of typhoid

fever. Reher, Eberth, Chantemesse, Widal, and Ernst have reported similar cases.

Since the typhoid bacillus produces toxins and toxalbumins, the symptoms of the disease are for the greater part to be referred to the *intoxication*. In the course of typhoid fever there appear in the blood certain bactericidal substances which cause a degeneration of typhoid-bacilli (cf. § 31). This may be demonstrated by the fact that (Widal-Gruber reaction), through the addition of serum from an individual ill or convalescent from typhoid fever, to a bouillon-culture of freely motile typhoid-bacilli, the latter become motionless, clump together (agglutination), sink to the bottom and die. This reaction may be used as a means of diagnosis, but is not of absolute certainty, since agglutination may be produced by the serum of individuals who have not had typhoid fever, and may be absent in the case of typhoid (Fischer).

The cultures of typhoid-bacilli show but few characteristic properties, and are therefore distinguished with difficulty from other widely distributed bacteria. Their properties are very similar to those of the *Bacillus coli communis* (cf. § 160). As a differential point may be mentioned the fact that typhoid bacilli produce no indol, while other similar bacilli, including the colon bacillus produce indol, so that bouillon-cultures turn red on the addition of potassium nitrite and sulphuric acid. Further, the typhoid-bacillus produces no gas in a two-per-cent. glucose-bouillon while the colon-bacillus produces gas. Finally, the typhoid-bacillus produces a faint acidity in milk without coagulation, while the colon-bacillus causes a strong acidity and coagulation of the milk within from twenty-four to forty-eight hours at 37° C.

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§ 160. The *Bacillus coli communis* or the *Bacterium coli commune* (Escherich) is a fission-fungus which is constantly present in the intestinal tract of man as well as of the mammalia. The bacilli are rods 2-3  $\mu$  long and 0.3-0.4  $\mu$  thick. They are motile and may possess as many as twenty flagella on one rod (Bunge, Luksch, Günther). The bacilli grow at room-temperature as well as at the temperature of the incubator. They form within the gelatin small, round, white colonies; upon its surface pellicle-like coatings. Upon potatoes they form moist

coatings of the yellow color of maize or pease (Günther). They do not form spores; and are not stained by Gram's method.

The *Bacillus coli* is very similar to the typhoid bacillus, but may be differentiated from it by proper methods of cultivation and by the employment of suitable reactions (cf. § 159). It was formerly regarded as a harmless saprophyte of the colon; but from later investigations it cannot be doubted that it also possesses pathogenic properties and may cause *degenerations* and *inflammations* in various tissues. Under suitable conditions (perforation or incarceration of the intestine, or impaction of fæces) it may pass into the peritoneal cavity and excite purulent inflammations, or at least take part with other bacteria in the production of inflammation. Further, it not infrequently gains access to the bile-passages and gall-bladder, as well as to the descending urinary passages and the kidneys, giving rise to inflammations of varying intensity. The bacillus has also been found in the meningeal exudate in certain cases of sepsis; it has been demonstrated also in pericarditis, bronchopneumonia, strumitis, angina of scarlet-fever, acute yellow atrophy of the liver (Stroebe, von Kahliden), and it cannot be doubted that it may be the cause of the affections named.

The similarity between the colon-bacillus and the typhoid-bacillus has led various authors to assume that the two bacilli are only varieties of the same species, and that the two forms may pass over into each other. At the present time the view prevails that the two bacilli are to be wholly separated from each other (§ 159.) Moreover, the form of bacillus which is described as *colon-bacillus* is not a very distinct form, but represents rather a *group of different varieties*. Three to four days after the inoculation of an animal with colon-bacilli the blood-serum of the infected animal produces an agglutination of colon-bacilli (*Jatta*), which is most marked in the case of that variety which was used for the inoculation. Colon-bacillus serum (*Jatta*) agglutinates typhoid-bacilli more markedly than does normal blood-serum. On the other hand, typhoid serum can agglutinate different varieties of colon-bacilli.

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§ 161. The *Bacillus pneumoniae* or the *Bacterium pneumoniae* is a bacillus discovered by Friedländer and Frobenius; and by them assumed to be the cause of inflammations, particularly of the lungs, nose (ozæna)



FIG. 446.—*Bacillus pneumoniae* (Friedländer). *a*, Oval cells and rows of cells with gelatinous capsule; *b*, rod with gelatinous capsule.  $\times 800$ .

middle ear, and meninges, more rarely of other organs. It is regarded by Friedländer as the chief cause of croupous pneumonia, but this view is without doubt incorrect (cf. § 153). According to Weichselbaum it can be demonstrated in only about five per cent. of the cases of lobar pneumonia. Baumgarten and others hold that its pathogenic significance is not yet firmly established,

inasmuch as other bacteria are found in association with it when present in the lungs.

The bacilli are found in the alveolar exudate, as well as in the pleuritic exudates that occur at the same time with the pulmonary inflammation. They appear partly in the form of rods (Fig. 446, *b*), partly as oval cells (*a*), and not infrequently form short chains. Since the oval cells are more numerous than the rod forms, the bacillus was originally classed with the cocci.

The bacilli possess a hyaline, mucin-like capsule, soluble in alkalis, and insoluble in acetic acid, which forms a common sheath around the chains of the bacilli (Fig. 446). Independent motion has not been observed.

When treated with iodine and alcohol after staining with gentian-violet the bacillus loses its stain and is in this way distinguished from the diplococcus. For staining it in sections with demonstration of the capsule Friedländer recommends the employment of an acid gentian-violet solution (concentrated alcoholic gentian-violet solution 50 parts, distilled water 100 parts, acetic acid 10 parts). After staining in this for twenty-four hours the sections are washed for a short time in a 0.1-per-cent. solution of acetic acid.

The bacilli grow upon nutrient gelatin at room-temperatures, and

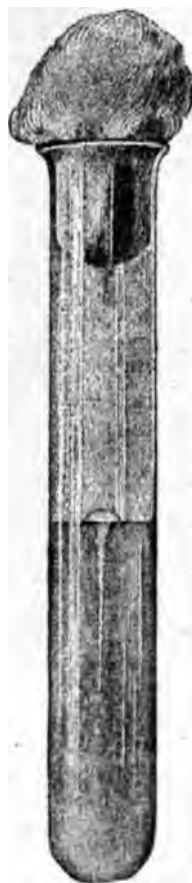


FIG. 447.—Nail-shaped stab-culture of the Friedländer pneumonia-bacillus in gelatin.

form upon the surface of the gelatin porcelain-white, button-shaped cultures consisting of oval and rod-shaped cells possessing no capsules. Stab-cultures in gelatin are nail-shaped (Fig. 447), the growth forming a knob-like prominence at the entrance of the stab-canal. This characteristic the pneumonia-bacilli share in common with many other bacteria. On blood-serum they form translucent, gray colonies; upon agar-agar jelly-like, grayish-white, and upon potatoes grayish-white or yellowish-white, creamy colonies. Spore-formation has not been observed.

Rabbits are almost completely immune to inoculation of the lungs. Mice on the other hand die of pleuritis and disseminated pneumonia within eighteen to thirty hours after injection of the bacilli into the lungs; the exudate as well as the blood contains bacilli with gelatinous capsules, partly free and partly enclosed within cells. A typical lobar pneumonia cannot be produced in the ordinary experimental animals by inoculation.

According to *Fricke* the bacterium of *Friedländer* is the chief representative of a group of bacteria which are classed together under the name *Bacillus mucosus capsulatus*, and represent varieties of a single species. The fission-fungus described as the *ozæna-bacillus* is identical with the pneumonia-bacillus, probably also the bacillus from the milk-fæces of nurslings described as the *Bacterium lactis aërogenes* (*Escherich*). It is possible that a greater etiological significance may be attached to it in so far as the origin of many diarrhæas is concerned.

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§ 162. As the **influenza-bacillus** (Fig. 448) there was described by R. Pfeiffer, in the year 1892, a bacillus whose occurrence in influenza has been many times confirmed; it is now regarded as the cause of influenza. In individuals suffering from influenza it is found in the catarrhally affected respiratory passages, occasionally also in the lungs; and the small bronchi may contain enormous numbers of the bacilli in pure culture. It is assumed that their multiplication in the respiratory tract gives rise to the inflammation, and that the bacilli produce poisons, which, when absorbed, cause the symptoms characteristic of influenza. The bacilli may also pass into the blood and become spread throughout the body. The inflammatory changes of internal organs occurring during influenza are to be referred in part to the influenza-bacillus, in part to the poisons produced by them, and in part to secondary infections.

The influenza-bacilli are very small, thin rods with rounded ends (Fig. 448), which lie separate or joined together in twos. They stain with the ordinary aniline dyes, but not by Gram's method. They may be cultivated at the body-temperature upon blood-agar or upon agar that



has been smeared with human or pigeon blood. They form upon this medium small, drop-like colonies as clear as water. They cannot be cultivated upon the other usual media. Spore-formation has not been observed. In apes a catarrhal inflammation of the respiratory tract may be produced by intratracheal injections of pure cultures. Rabbits may be poisoned through the incorporation into their bodies of cultures; and are affected in consequence by a paralytic weakening of the muscles and dyspnoea. According to Cantani the poison produced by the bacilli exerts its effects particularly upon the central nervous system.



FIG. 448. — Influenza-bacilli and pus-corpuscles, from sputum (fuchsin).  $\times 1,000$ .

According to investigations by *Czaplewski* and *Hensel* ("Bakteriolog. Untersuch. über Keuchhusten," *Centrbl. f. Bakt.*, xxii., 1897) and *Koplik* ("Die Bakteriologie des Keuchhustens," *Centrbl. f. Bakt.*, xxii., 1897), there is found in the respiratory tract in **whooping-cough** a small, non-motile bacillus similar to the influenza-bacillus, which is thought to be the cause of whooping-cough. *Luzzatto* ("Zur Aetiologie des Keuchhustens," *Centrbl. f. Bakt.*, xxvii., 1900) found in cases of whooping-cough two bacilli, but was unable to determine with certainty their pathogenic significance. *Jochmann* and *Krause* ("Aetiologie des Keuchhustens," *Zeit. f. Hyg.*, 86 Bd., 1901) found in whooping-cough a bacillus resembling the influenza-bacillus (*Bacillus pertussis*, *Eppendorf*); this could be cultivated upon media containing hæmoglobin; they regard it as the cause of whooping-cough. Their bacillus is not identical with the one described by *Czaplewsky* and *Hensel*.

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§ 163. The *Bacillus diphtheriæ* (Fig. 449) was first thoroughly studied by Löffler; it is found in the croupous membrane occurring in diphtheria, and is regarded as the cause of this disease. In the internal organs, as the spleen and lymph-glands, it is either entirely absent or present in such slight numbers that it can be demonstrated only by methods of cultivation.

The bacilli are 1.5-3  $\mu$  long, often somewhat thickened (club-shaped) or pointed at the ends. When stained the bacilli appear spotted or granular. They stain best in a staining-solution composed of 30 c.c. of concentrated alcoholic methylene-blue solution in 100 c.c. of 0.0001 per cent. potassium hydroxide solution, after which the sections are treated

for a few seconds in a 0.5-per-cent. solution of acetic acid and then with alcohol. In stained sections the bacilli often appear segmented. They also stain by Gram's method, provided the treatment with Lugol's solution and alcohol is of brief duration.

Diphtheria-bacilli grow best in the presence of air (Löffler) on a mixture of three parts of calf's or sheep's serum, and one part of neutralized veal-bouillon, to which one per cent. of peptone, one per cent. of grape-sugar, and 0.5 per cent. of common salt are added; or upon blood-serum and agar-agar with an addition of ten per cent. glycerin or of sugar-containing bouillon (Kolisko, Paltauf, Kitasato). They form grayish-white colonies. For their development they need a temperature above 20° C.; they grow best at 33°–37° C. They are resistant to drying; but may be quickly killed by moist heat. Spore-formation has not been observed.

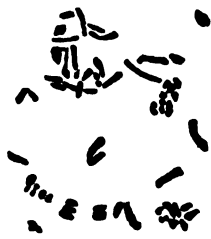


FIG. 449.—Diphtheria-bacilli from a pure culture. Streak-preparation (methylene-blue).  $\times 1,000$ .

Guinea-pigs inoculated subcutaneously with cultures of diphtheria-bacilli die in two to three days (Löffler, Roux, Yersin); whitish deposits and a hæmorrhagic œdema are found at the point of the inoculation. The inoculation-area contains bacilli, the internal organs, on the contrary, are free. The introduction of cultures into the opened trachea of rabbits, chickens, and pigeons, as well as the inoculation of the conjunctiva of rabbits and the vagina of guinea-pigs is followed by an inflammation with the formation of a pseudomembrane. Sheep, horses, cats, dogs, cows, rabbits, and pigeons are susceptible to subcutaneous inoculation. Rats and white mice are nearly immune.

Roux, Yersin, Löffler, Spronck, and others observed the later appearance of paralysis in pigeons and guinea-pigs surviving the inoculation. Roux and Yersin assert that the intravenous injection of filtered bouillon-cultures free from bacteria will cause in guinea-pigs and rabbits after two to three days a severe illness characterized by paralysis and fatal termination.

The virulence of the cultures varies greatly. Diphtheria bacilli produce in the human body and also in cultures toxins, which may be precipitated by alcohol and obtained as a whitish powder. This substance has been classed with the toxalbumins, but according to Brieger and Boer it is not an albuminous body. It is also formed when the bacilli are cultivated in alkaline urine (Guinochet). According to Kossel the poison is formed within the bacterial cell from its food-material and then secreted.

Water-solutions of the poison injected subcutaneously into animals cause local tissue-necrosis, hæmorrhagic œdema, and inflammation; when taken up into the body-juices they give rise to pleural effusions, nephritis, fatty degeneration of the liver, and paralysis.

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**Diphtheria** in man is characterized by an inflammation involving usually the mucous membrane of the pharynx, palate, arch of the palate, and upper respiratory passages. It appears as a *febrile infectious disease associated with symptoms of intoxication* and gives rise to local *croupous exudations*, in part also to diphtheritic sloughings (cf. § 92, Figs. 189, 190). The croupous membranes constitute the most striking feature of the disease; they are found in the throat and nose usually in the form of circumscribed flat patches, more rarely uniformly spread over larger areas; or, on the other hand, they may form a continuous layer lining

the larynx and trachea, or even the bronchi. Beneath the croupous membrane the epithelium is for the greater part lost; and the connective tissue of the mucosa is hyperæmic, infiltrated, and swollen (Fig. 190). In severe cases the superficial layers of the connective tissue are necrotic in places, most frequently in the tonsils, which are more or less, often markedly, swollen. Of the deeper tissues the neighboring cervical *lymph-glands* in particular are swollen, and often show, when examined microscopically, small foci of necrosis and degeneration. Of the internal organs the kidneys especially are accustomed to show changes, in the form of a more or less severe fatty degeneration of the epithelium and of the cells of the capillary walls; not infrequently they also present swellings and focal areas of small-celled infiltration. In the spleen there are frequently found areas of degeneration in the white-appearing follicles, in which the cells are more or less necrosed, in part disintegrated and have lost their nuclei. In the blood many of the leucocytes show fatty degeneration. Degenerative changes and areas of inflammation are not infrequently found in the heart-muscle. Paralysis are caused by degeneration and necrosis (Katz) of the ganglion-cells of the medulla oblongata and of the spinal cord and of the corresponding nerves.

The lungs are not demonstrably changed by the diphtheria poison, but bronchopneumonia, due to the aspiration of irritating bronchial contents or to an extension of the bronchial inflammation to the respiratory parenchyma, is of frequent occurrence.

The *local inflammations of the mucous membranes* as well as the *symptoms of intoxication may be caused by the diphtheria bacilli and their toxins alone*; but it must be noted that *streptococci* are almost regularly present in the diseased area, and that a *pure streptococcus infection* may present the clinical and anatomical picture of a "*diphtheria*." When both bacteria are present the injurious effect of one may be supplemented by that of the other, and the presence of streptococci appears to increase the virulence of the bacilli. In severe forms of diphtheria streptococci are usually present in great numbers; yet every streptococcus infection does not warrant a bad prognosis, since the virulence of the cocci varies greatly.

In the course of the infection with diphtheria bacilli there arise in the body *antitoxins*, which nullify the poisonous action of the toxins, and aid and make possible recovery from the disease. The formation of antitoxins follows the inoculation of animals with attenuated bacilli, and upon this rests the possibility of obtaining from animals (sheep, horses), that have been repeatedly inoculated with bacilli of increasing virulence, a serum which contains an antitoxin of value for therapeutic purposes (cf. § 32).

*Lehmann and Neumann* call the diphtheria bacillus *corynebacterium* on account of the club-shaped appearance of the rods. Since the bacilli can also form *branching threads* in cultures, they class it with the *hyphomycetes*, among which the tubercle-bacillus and the fungus of actinomyces (oöspora) are also classed by them and others.

*Ehrlich* ("Die Constitution des Diphtherie-Giftes," *Deut. med. Wochenschr.*, 1898, p. 597) distinguishes different kinds of poisons produced by the diphtheria-bacillus, namely, *toxins* and *toxons*, these again representing no bodies of definite unity, but breaking up into several subdivisions (prototoxin, deuterotoxin, and tritotoxin) which are distinguished by the different degrees of avidity with which they unite with the antitoxin. He further assumes that there are present in the poison-molecule two atom-complexes independent of each other, one of which is of haptophorous nature and brings about the union with the antitoxin or with the corresponding side-chains of the

cells. The other atom-complex is toxophorous—that is, it is the cause of the specific action of the poison (cf. § 82).

According to *Löffler, von Hoffmann, Roux, Yersin, Babes*, and others there are very frequently present in the mouth and throat bacilli, which are often designated **pseudo-diphtheria bacilli**. These resemble the true bacilli of diphtheria and can be distinguished from them only in cultures. Since the diphtheria-bacilli can lose their virulence, it is not impossible (*Roux, Yersin*) that both bacilli represent varieties of the same species. According to *Kober* and others diphtheria-bacilli are also found in the mouths of healthy individuals.

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- See also § 32.

§ 164. The *Bacillus tetani* (Kitasato) is a fine, slender bacillus (Fig. 450) which is widely distributed throughout the superficial layers of the earth, and is to be regarded as the cause of tetanus. According to observations made by Nicolaier in 1885, it is often possible to produce in mice, guinea-pigs, and rabbits, by means of subcutaneous inoculation of surface-earth, a typical tetanus with fatal termination, due to this bacillus.

It was first demonstrated by Rosenbach in 1886 that this same form of bacillus is present in the seat of injury in cases of tetanus in man following trauma or freezing; and that when inoculated into guinea-pigs and mice it again produces tetanus. Since that time this discovery has been many times corroborated. The bacillus is not present in an isolated condition in either the earth or in the infected wound; and consequently the inoculations were made with a mixture of bacteria. Attempts to

isolate by cultures the bacillus that was regarded as the cause of tetanus were unsuccessfully made by many investigators. In 1889, in Koch's laboratory, Kitasato succeeded in isolating the tetanus-bacillus by allowing the mixed cultures to remain in the incubator for several days and heating upon a water-bath at 80° C. for a half-hour or an hour, and then subsequently keeping plate-cultures in an atmosphere of hydrogen. The bacteria growing in association with the tetanus-bacillus are killed, while the tetanus-bacillus is preserved.

The tetanus-bacillus is anaërobic and thrives very well in an atmosphere of hydrogen, but not in carbonic-acid gas. It grows on ordinary peptone-agar that is slightly alkaline, on blood-serum, and in nutrient gelatin. The latter is liquefied with evolution of gas. The addition of from 1.5 to 2 per cent. grape-sugar to agar-agar accelerates the growth; a temperature of 36°–38° C. is most favorable for its development. It forms long, thin, bristle-shaped rods which form terminal spores (Fig.



FIG. 450.—Tetanus-bacilli with terminal spores.  $\times$  1,000.

450) giving rise to a spherical swelling at the end of the rod (knobbed bacilli). In cultures it may form long pseudothreads. The cultures give off an offensive odor; gelatin is slowly liquefied. The bacilli stain by Gram's method. They are motile except during the time of spore-formation, and possess peritrichous flagella. Pure cultures inoculated into horses, asses, guinea-pigs, mice, rats, and rabbits cause tetanus, but in the case of rabbits larger amounts must be injected. The tetanic contractures begin in the neighborhood of the point of inoculation. Suppuration does not occur at the point of inoculation. The bacilli cannot be demonstrated after the death of the animal, and are never found in the tissues except at the seat of inoculation.

According to experimental investigations by Kitasato, the filtrate of bouillon-cultures of the bacilli, which does not contain bacilli, acts in the same way as cultures containing the bacilli, and guinea-pigs are especially sensitive to it. The blood or transudate from the thoracic cavity of an animal infected with tetanus, although free from bacilli, will cause tetanus when injected into mice. It may therefore be assumed that in tetanus there is an *intoxication* with a poison (*tetanotoxin*) which is diffused throughout the blood. This poison is (Kitasato) destroyed by heat (at a temperature of 65° C. and over, within a few minutes), and by direct sunlight (in fifteen to eighteen hours), and in diffuse daylight loses its virulence within a few weeks. According to investigations of Brieger and Cohn the purified poison gives no reaction for albumin, and therefore is not a toxalbumin.

The infection—intoxication—of man takes place usually through the medium of small wounds; idiopathic or rheumatic tetanus, which does not start from wounds, may arise through infection of the mouth-cavity and the respiratory tract (Carbone, Perrero, Thalmann). A preëxisting catarrh favors the infection (Thalmann). The tetanus-toxin affects chiefly the nervous system.

The *Bacillus œdematis maligni* (*Vibrio septique* of Pasteur) is an anaërobic bacillus first carefully studied by R. Koch. It is present in various putrefying substances, and is almost never absent from earth fertilized by decomposing fluids or liquid manure. The bacilli are 3–3.5  $\mu$  long, and 1–1.1  $\mu$  broad; they often form long pseudothreads. They resemble the anthrax-bacilli, though somewhat more slender, are rounded at the ends, and not sharply cut across. In spore-formation a swelling of the rod takes place, as in the case of the *Bacillus butyricus*, so that spindle- and tadpole-shaped forms arise.

The bacillus is motile, and possesses flagella on the ends as well as on the sides. It is not stained by Gram's method.

It grows in nutrient gelatin as well as in agar and coagulated blood-serum, but must be introduced deeply into the medium and protected from the air. Nutrient gelatin to which one to two per cent. of grape-sugar has been added is an especially favorable medium (Flügge). Nutrient gelatin and blood-serum are liquefied, the latter with evolution of gas.

The bacillus can be easily obtained by sewing up garden-earth under the skin of a guinea-pig, care being taken to prevent the access of air to the point of inoculation. The ensuing multiplication of the bacteria excites a progressive œdematous swelling of the subcutaneous tissue. At a later stage the bacilli spread over the serous membranes, and involve the spleen and other organs.

Mice, guinea-pigs, horses, sheep, and swine are susceptible to the bacilli; cattle are not.

According to observations by Brieger, Ehrlich, Chauveau, Arloing, and others, the bacilli of malignant œdema may also occasionally develop in the human body, particularly when the tissues are poorly nourished and the bacilli through any accident—puncture of a hypodermic syringe—get into the deeper tissues. They excite gangrenous processes associated with hæmorrhagic œdema and gas-production.

As the *Bacillus phlegmones emphysematosæ* R. Fraenkel in 1892 described an anaërobic bacillus which in many cases is to be regarded as the cause of phlegmonous inflammation associated with gas-formation. According to Fraenkel the bacillus is motile and only exceptionally forms spores. It occurs in the external world (by Fraenkel it was demonstrated upon a splinter of wood with which a man dying of gas-phlegmon had been wounded); and when injected subcutaneously into guinea-pigs or sparrows produces a progressive gangrenous process with disintegration of the subcutaneous tissues and muscle, as well as free collections of fluid and gas. Intravenous injection into rabbits and guinea-pigs is followed by the formation of gas in the internal organs.

It is probable that this bacillus is identical with one described by Ernst, Welch, and Nuttall (by the latter as *Bacillus aerogenes capsulatus*) as the cause of "foamy liver" ("*Schaumleber*") (Ernst)—that is, with a bacillus which is regarded as the cause of gas-formation in the human liver (Ernst). The condition of "foamy organs" (*Schaumorgane*) probably arises (Fraenkel) from the fact that the bacillus in question gains an entrance before death into the tissues, into the liver in particular.

According to *Vaillard* and *Vincent* tetanus does not follow the inoculation of tetanus-bacilli deprived of poison. Consequently it must be assumed that the bacilli can increase in the tissues of man and animals and lead to poisoning only under certain conditions, when at the same time the poison of tetanus or of other bacteria (for example, *Bacillus prodigiosus*) gain access to the tissues. *Blumenthal* holds that the bacilli secrete a ferment which produces, within the organism, the tetanus poison.

According to investigations by *Kitasato*, *Tizzoni*, *Cattani*, *Baquis*, *Behring*, and others, susceptible animals may be made immune against tetanus, or, more correctly, may be made poison-proof against the tetanus-poison. The blood of animals thus made poison-proof, possesses the power of destroying the tetanus-poison, and consequently it is possible to immunize susceptible animals with the curative serum derived from this blood, or to cure an attack of tetanus after the disease has already been acquired (cf. § 32).

As regards the bacteria of hæmorrhagic infection, see § 44.

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(*Bacillus Oedematis Maligni. Bacillus Phlegmones Emphysematosæ.*)

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§ 165. The **bacillus of bubonic plague** (*Bacillus pestis*) was discovered in 1894 by Kitasato and Yersin, of the Japanese and French commission, while investigating an epidemic which had broken out in Hong-Kong. The pest bacillus is a small rod with rounded ends (resembling the bacillus of chicken-cholera). It stains easily with aniline dyes, especially well with methylene-blue, and in part shows an exquisite polar-staining (Fig. 451). It is decolorized by Gram's method. It is found in all cases of plague, in especial abundance in the swollen lymph-glands, but also in the spleen and blood. It may be cultivated upon the various media, and forms bluish-gray colonies, which contain rods of various lengths. It multiplies abundantly in bouillon containing sugar, and forms toxins. Independent movements have not been observed. Spores



are not formed. The bacilli are easily killed by warming, but are able to withstand drying well.

The *bubonic plague*, which destroyed great numbers of the inhabitants of Europe, at the close of the seventeenth and beginning of the eighteenth centuries ("Black Death"), has since 1720 almost disappeared from Europe and has shown itself only here and there in Eastern Europe. In different countries of Asia (Yunnan in China, Arabia, Mesopotamia), and in the interior of Africa (Koch) the disease seems to be endemic, and spreads from time to time in the same manner as cholera.

Man is infected usually through the skin, more rarely from the mucous membrane of the mouth, nose, throat, and conjunctiva, still more rarely from the deeper parts of the respiratory tract, although cases of primary pest-bronchitis and pest-pneumonia occur. Small wounds usually form the avenue of entrance in the skin, but it appears (Albrecht and Ghon) that a violent rubbing of an area of the skin with infected fingers or clothing may be sufficient to bring about an infection.

The bacilli are taken up by the lymph-vessels and taken to the regional *lymph-glands*, where they cause a very marked swelling of the infected gland or group of glands—the *primary bubo*. Through the infection of lymph-glands situated farther along the lymph-system there arise *primary buboes of the second class*, and by metastasis through the blood-stream *secondary buboes* are formed. The plague is thus characterized in the first place by an *acute polyadenitis*. Since the poisons which are in association with the bodies of the pest-bacilli exert a degenerative and necrotic effect upon the vessel-walls, numerous *hæmorrhages* are also caused, and these are absent only in rare cases. To these changes there are also added circumscribed foci in the spleen, liver, kidneys, lungs, skin, etc. With the exception, therefore, of those cases in which the pest-infection is confined to the primary bubo, the disease is to be regarded as a *general infection* (Albrecht and Ghon), which arises from the taking-up of bacteria from a primary focus of infection, and runs its course with the clinical picture of a *polyadenitis* and a severe *hæmorrhagic septicæmia*.

The individual foci are characterized by tissue-necroses of the nature of *coagulation-necrosis* (Albrecht and Ghon), as well as by *severe exudations*, *inflammation*, and *hæmorrhage*, and are caused by the presence of extraordinarily large numbers of bacilli. The lymph-glands of the primary bubo show either wholly or for the chief part the appearance of hæmorrhagic infarction, and are swollen and of a medullary consistence. After the course of a few days they also show yellow necrotic areas which later undergo liquefaction. When the disease has lasted longer than six days, the liquefaction of the lymph-glands may take on the character of a *suppuration*.

The tissues in the neighborhood of the lymph-gland are always more or less œdematously swollen, infiltrated with blood; and hæmorrhages are also found in the walls of the neighboring large veins.

The secondary inflammations of the lymph-glands and of the lymph-adenoid tissue of the mouth and throat do not usually cause such a

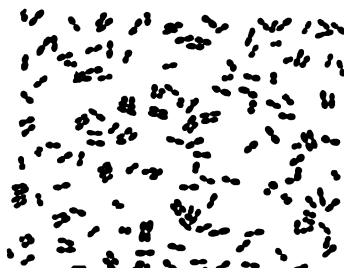


FIG. 451.—Plague bacilli (fuchsin).  $\times 500$ .

marked degree of swelling as do the primary; they resemble the medullary swelling occurring in typhoid fever. The surrounding tissues are also less changed, but if the process be prolonged the picture comes to resemble that of the primary buboes.

The spleen of plague-patients is somewhat swollen, dark red, finely granular, shagreened (Albrecht and Ghon), and often contains small necrotic foci, which are caused by the development of the bacilli in great numbers.

In the glandular organs and in the skin, there occur, besides hæmorrhages, also necrotic areas and exudative inflammations, all due to the presence of bacilli. In the lungs there may occur, in addition to the primary pest-bronchopneumonia, secondary metastatic focal inflammations and aspiration-bronchopneumonias.

The majority of individuals infected with pest die within the first eight days, but others may live several weeks and then die of marasmus.

Not infrequently *secondary infections*, particularly of streptococci and diplococci, are associated with the pest-infection. They arise chiefly in the tonsils and follicular glands of the tongue following the changes caused by the pest-bacilli (Albrecht and Ghon).

Among *animals, rats, mice, apes, and cats are especially susceptible to pest*; and in these, particularly in rats, spontaneous infections occur, so that they may aid in the spread of epidemics. Swine and dogs are less susceptible, birds still less so.

The changes in infected animals agree in general with those observed in man. The infection may remain local or become general. After the lymphadenitis and the multiple hæmorrhages there arise also miliary, tubercle-like foci in the spleen, liver, and lungs. The course is usually acute, rarely chronic. In the latter case the larger necrotic foci may be encapsulated by connective tissue. The animals are easily infected from the skin, as well as from the mucous membranes of the intestinal and respiratory tracts; and such infection may take place from an uninjured mucous membrane. The inoculation of one mouse confined in a cage with other mice may give rise to a cage-epidemic (Schottelius).

Attempts to *immunize animals and man against pest by means of dead and attenuated pest-bacilli* have been many times carried out, especially by *Yersin, Haffkin, and Lustig*; and have been successful in so far that rodents, horses, and apes have been rendered immune against inoculations otherwise fatal. According to the reports of such attempts in man, a smaller per cent. of inoculated individuals acquire the disease than of those not inoculated; but doubt is thrown upon the results of these inoculations by other authors (*Bitter*). Further, *attempts at immunization and healing have been made in man, with the serum of animals which have been rendered immune*, particularly of horses (*Yersin, Lustig*); and different authors ascribe to such serum a favorable influence.

During the last several years, as the result of the spread of plague in India and its appearance in Europe, numerous articles upon pest have appeared. The most thorough pathological anatomical and experimental investigations are those carried out by *Albrecht and Ghon*, whose articles have been used chiefly in the preparation of the text as given above.

*Sticker* differentiates the following forms of pest according to the first localization of the bacilli: (1) Bubonic plague (the most common form); (2) the cutaneous form (formation of vesicles and ulcers or furuncle-like inflammations); (3) the pulmonary form; (4) the intestinal form.

Some years ago *Sanarelli* ("Sur la fièvre jaune," *Ann. de l'Inst. Pasteur*, 1897; *Cent. f. Bakt.*, xii.) described as the cause of **yellow fever** a bacillus whose properties he sought to determine by means of culture-experiments and animal-inoculations. He is still of the opinion that his *Bacillus icteroides* is the cause of yellow fever ("Zur Lehre vom gelben Fieber," *Abh. f. Bakt.*, xxvii., 1900), and reports favorably of the protective and curative effects ("Expér. sur l'emploi du sérum curatif et préventif de la fièvre

jaune," *Ann. de l'Inst. Pasteur*, 1898) of his serum obtained from vaccinated animals (dogs, horses, cattle). *Freire* ("Man. sur la bactériologie, pathogénie et traitement de la fièvre jaune," Rio de Janeiro, 1898, *Cbl. f. Bakt.*, xxvi.) on the other hand opposes energetically the correctness of Sanarelli's views, and maintains that the cause of yellow fever is a coccus earlier described by him, which he calls the *Micrococcus xanthogenicus*. By inoculations of the same into dogs, guinea-pigs, and rabbits he was able to produce a disease resembling yellow fever, and likewise reports successful protective inoculations with attenuated cultures.

Through the investigations of *Ducrey*, *Krefting*, and *Petersen* (cf. *Petersen*, "Ulcus Molle," *Arch. f. Derm.*, xxix., 1894; xxx., 1895) it is probable that the *ulcus molle* or *soft chancre* is caused by a bacillus. This view is, however, opposed by competent authors (*Finger*, "Die Syphilis und die venerischen Krankheiten," Leipzig, 1896); and the opinion is advanced that there is no single specific virus of soft chancre. It must also be remarked that attempts to cultivate the chancre bacillus have not been successful. (See also "Observations on the Distribution and Culture of the Chancroid Bacillus, by *Davis*, *Jour. of Med. Res.*, 1902.)

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§ 166. The *Bacillus tuberculosis* is the cause of the infectious disease occurring so frequently in man and the domestic animals which is known ordinarily as *tuberculosis*, but is also sometimes called *pearl disease* (*Perlsucht*) in animals.

The tubercle-bacillus was discovered and thoroughly studied by Koch in 1882. It is a slender rod (Fig. 452), of 1.5–4  $\mu$  in length, and is usually slightly curved. It may be stained by aniline-dyes (fuchsin, gentian-violet) to an aqueous solution of which an alkali, or carbolic acid, or aniline oil is added. The bacilli when once stained retain the stain, even when the preparation is decolorized in dilute sulphuric acid, or nitric acid, or hydrochloric acid and alcohol.

The stained bacilli not infrequently show in their interior clear, shin-

ing, unstained areas, or are composed of little stained spherules. Koch formerly regarded these clear spots as spores, and this view was generally accepted for a long time. Nevertheless, a germination of these structures could not be demonstrated, and at the present time they are no longer regarded as spores. Consequently, the tubercle-bacilli form no special resistant forms, but on the other hand the bacilli are more resistant against external influences, for example, against drying, than are many other bacteria.

The tubercle-bacilli may be cultivated at the body temperature and in the presence of oxygen upon coagulated blood-serum, blood-serum-gelatin, nutrient agar, and in bouillon. They increase, however, very slowly, so that only on the seventh to tenth day or even later, do the cultures become visible in the form of dull-white flakes resembling little scales. Larger cultures form, on the surface of coagulated blood-serum, whitish, irregularly shaped, lustreless deposits. According to Nocard, Roux, and Bischoff the growth of the bacilli is greatly aided by the addition of glycerin (four to eight per cent.). Pawlowski succeeded in

cultivating them upon potato in sealed glass-tubes. In cultures the tubercle-bacilli also form threads, which in part show branching.

At temperatures below 28° C. and above 42° C. the growth of the bacilli ceases. Sunlight kills the bacilli in a short time (Koch).

If the bacilli from pure cultures are inoculated into experimental animals, tuberculosis is produced in these; and the infection is transmitted as well by inoculation under the skin, or into the peritoneal cavity, or the anterior chamber of the eye, as also by inhalation of an atomized suspension of the culture,

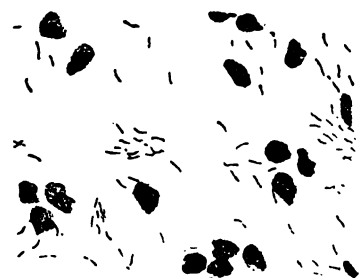


FIG. 432.—Tubercle-bacilli. Sputum from a man suffering with pulmonary tuberculosis. Smear-preparation on cover-glass, stained with fuchsin and methylene-blue.  $\times 400$ .

by feeding, and by injection of bacilli into the veins. Guinea-pigs, rabbits, cats and gray field mice are especially susceptible; dogs, rats, and white mice less so.

**Infection of man and of animals** occurs from the taking up of tubercle-bacilli from the lungs, respiratory passages, and the intestinal tract, or from wounds and tissue-ulcerations. In the alimentary tract the lymphadenoid apparatus, tonsils, and the intestinal lymph-follicles form the most frequent avenue of entrance. Further, a direct transmission of the bacilli from the mother to the *fetus in utero*, may occur, but this is rare.

The bacilli are spread throughout the external world chiefly by the sputa, under certain conditions also by the faeces and urine, further from tuberculous ulcers, or from tuberculous organs which are taken from living or dead persons. Since the bacilli are rather resistant, they may be preserved outside of the animal body for a long time under certain conditions, and may become mixed with the respired air, as well as with the food and drink. The milk of tuberculous cows contains the bacilli especially when the udder is diseased; but the bacilli may also pass into the milk when no disease of the udder can be demonstrated (Hirschberg, Ernst, Leuch).

If the bacilli succeed in developing and multiplying in any tissue of



the human body, they lead by a series of changes to the formation of *nodular masses of granulation tissue* or **tubercles**, which remain devoid of



FIG. 453.



FIG. 454.

FIG. 453.—Tissue-changes caused by fresh invasion of tubercle-bacilli. (After Baumgartner.) *a*, Proliferating connective tissue; *b*, transverse section of a blood-vessel; *c*, karyomitoses in connective tissue; *d*, mitoses of an endothelial cell in a blood-vessel; *e*, emigrated leucocytes.  $\times 350$ .

FIG. 454.—Giant-cell containing bacilli, and showing necrotic centre, from a tubercle. Stained with gentian-violet and vesuvium, mounted in Canada balsam.  $\times 350$ .

blood-vessels, and after reaching a certain stage of development undergo retrogressive changes.

The first effect of the development of the bacilli in a tissue is a *tissue-degeneration*, in which (Wechsberg) the tissue-cells as well as the connective-tissue ground-substance over a larger or smaller area are destroyed. To the degenerative processes there is added then on the one hand an inflammatory exudation—that is, *emigration of leucocytes*—and on the other hand, a *proliferation of the tissue-cells remaining preserved* within the affected area (Fig. 453, *a*). This is accomplished by karyomitosis (*c*, *d*), and leads in the connective tissue to the formation of *epithelial-like fibroblasts rich in protoplasm*, which are usually designated as *epithelioid cells* (*a*). Since the process of cell-division is many times repeated, there arise heaps of epithelioid cells (*a*), in which the bacilli lie partly between the cells and partly in the cells themselves (Fig. 453).

Through the proliferation of the cells the remaining connective-tissue stroma of the original tissue is pushed farther and farther apart, so that the individual cells come finally to be separated from one another only by scanty fibres, whose general arrangement is in the

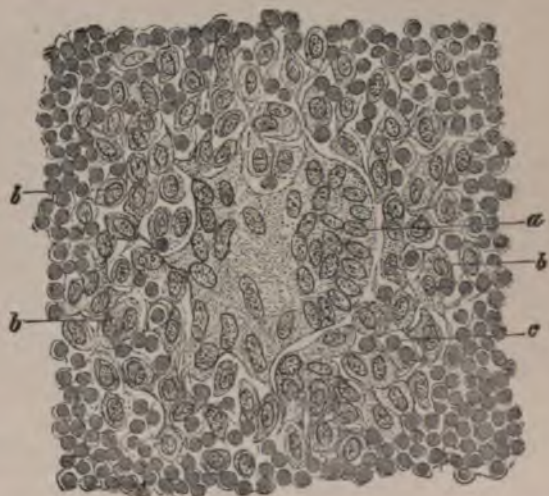


FIG. 455.—Tubercle from a fungous granulation of bone (Müller's fluid, Bismarck brown). *a*, Giant-cell; *b*, epithelioid cells; *c*, lymphoid cells.  $\times 400$ .

form of a network, which is consequently called the *reticulum of the tubercle*.

The proliferating cells have for the chief part but one or two nuclei (Figs. 453, *a*; 455, *b*), but usually multinuclear cells (*giant cells*) also

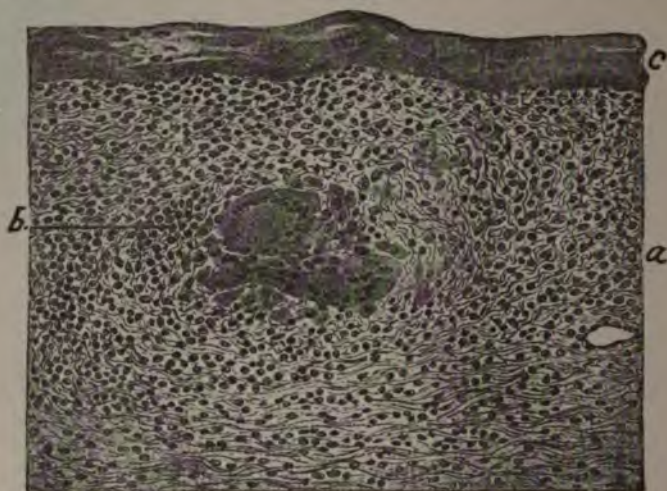


FIG. 456.—Tuberculosis of the pleura (alcohol, Van Gieson's). *a*, Thickened and proliferating pleura; *b*, tubercle with giant-cells; *c*, deposit of fibrin.  $\times 200$ .

appear (Figs. 454, 455, *a*), and these often enclose a very large number of large, oval, bladder-shaped nuclei, as well as bacilli. The nuclei of

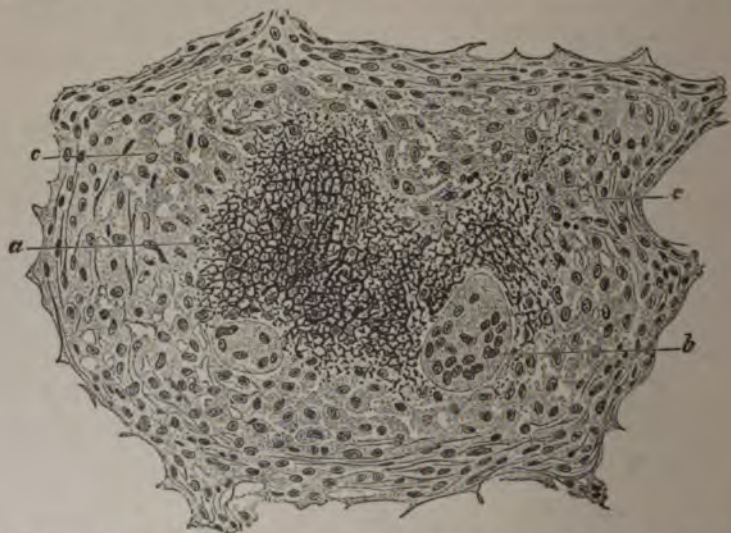


FIG. 457.—Large-celled tubercle containing fibrin, from a tuberculous lung (alcohol, fibrin-stain). *a*, Fibrin; *b*, giant-cell; *c*, large-celled tissue.  $\times 300$ .

the giant cells are almost always irregularly distributed throughout the protoplasm of the cell, sometimes grouped in the form of a wreath or



horseshoe, sometimes massed at one pole or at two or more points (Figs. 454 to 459). The non-nucleated portions of the giant cells, when properly stained, present conditions of degeneration and necrobiosis of the protoplasm, which are brought about by the action of the bacilli present in the giant-cells (Figs. 454, 458, *c*).

The *emigration of leucocytes*, which may take place even at the beginning of the process, accompanies also the later proliferation (Figs. 453, *e*, 455, *c*).

*New vessels are not formed* within the tubercle; and the *old vessels are closed* through the proliferation of the vessel-walls. Usually the *new-formation of connective tissue stops with the production of fibroblasts*.

If a large-celled nodule results from the cell-proliferation, the emigration of cells leads first to a collection of small round-cells at the periphery of the nodule (Figs. 455, *c*, 456, *b*), but in part also to an infiltration of the same with round cells, which may be so marked that the large cells are either partly or wholly concealed, and the picture presented is that of a *small-celled tubercle*. If the emigration of the cells at the very beginning is very abundant the tubercle assumes from the start the char-

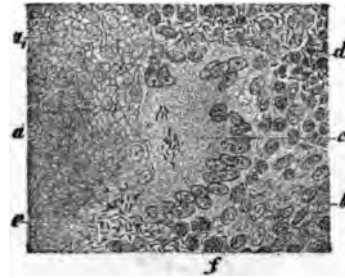


FIG. 458.—Caseous necrosis of tuberculous granulation tissue (alcohol, fuchsin, aniline blue). *a*, Granular, lumpy caseous masses; *b*, fibrocellular tissue; *c*, giant-cell with bacilli; *d*, bacilli in cellular tissue; *e*, bacilli in necrotic tissue; *f*, bacilli enclosed in cells.  $\times 200$ .

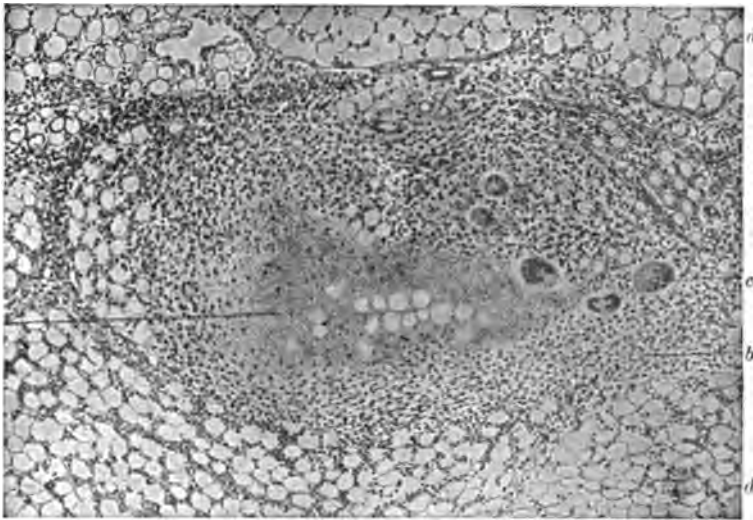


FIG. 459.—Section of miliary tubercle of the omentum (alcohol, hematoxylin, eosin). *a*, Caseous centre containing remains of fat-cells; *b*, fibrocellular periphery; *c*, giant-cells; *d*, fat tissue.  $\times 100$ .

acter of a *small-celled focus*, though mononuclear *fibroblasts* or *giant-cells* may be demonstrated in the focus without much difficulty (Fig. 456, *b*).

A serous exudation is also usually associated with the cellular emigration, and *fibrin* may be formed both *within the tubercle itself* (Fig. 457, *a*) and *in its neighborhood*.

At the height of its development the tubercle forms a small, *gray, translucent cellular nodule*, which may reach the size of a millet-seed, and encloses in its tissue tubercle-bacilli in larger or smaller numbers. When

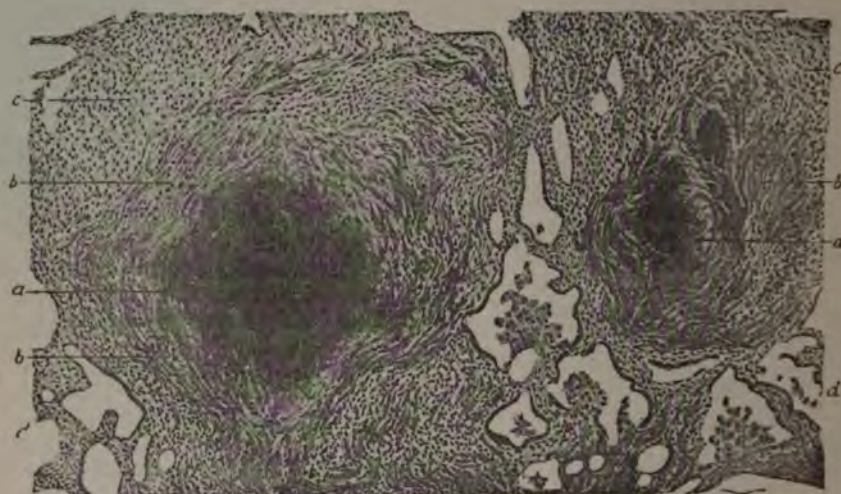


FIG. 460.—Fibrocaseous tubercle of the lung (alcohol, Van Gieson's). *a*, Caseous centre; *b*, thick, homogeneous connective tissue poor in nuclei; *c*, connective tissue rich in cells; *d*, lung tissue.  $\times 80$ .

it has reached a certain size *retrogressive changes* usually appear in its centre, the tubercle in consequence becoming cloudy, opaque, and of a

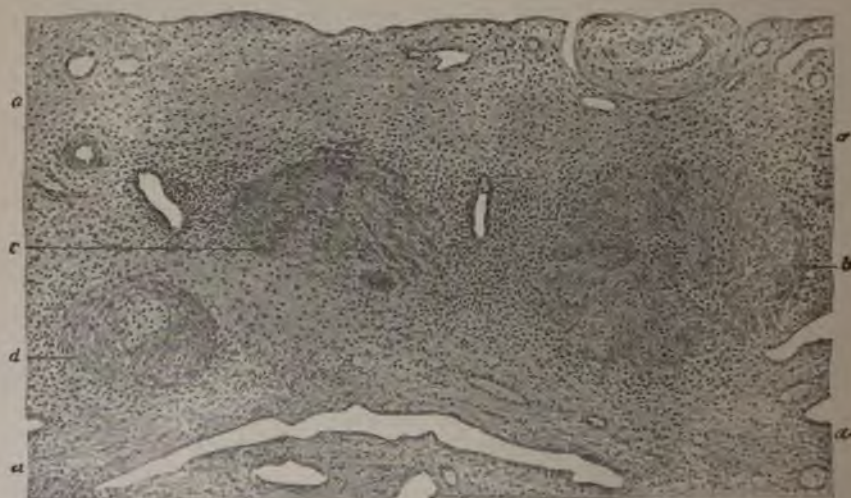


FIG. 461.—Fibrous tubercle in the thickened synovial membrane of the knee-joint (alcohol, hematoxylin, picric acid, fuchsin). *a*, Connective tissue; *b*, *c*, *d*, fibrous tubercle.  $\times 75$ .

white or *grayish-white* or *yellowish-white color*—these changes being designated as caseation.

The caseation of the tubercle is dependent on the one hand upon a



*necrobiosis of the cells*, and on the other upon the *deposit of coagulated substances* in the spaces between the cells. The cell-necrosis is characterized by a loss of the nuclei and a transformation of the cells into lumpy masses which later disintegrate and become granular (Fig. 458 *a*, *a*). The deposit between the cells consists either of a network of fibrin (Fig. 457, *a*) or of a granular or hyaline reticulated fibrinoid substance resembling fibrin but which does not take the Weigert's fibrin stain and is stained yellow by Van Gieson's. In the further course of the process of caseation the fibrin and fibrinoid substance disintegrate into a granular mass which fuses with the cell-detritus, so that the central part of the tubercle consists of a lumpy granular mass (Figs. 459, *a*, 460, *a*) which takes a weak diffuse stain with nuclear stains.

The caseation affects at first the central portion of the tubercle, and is usually confined to this, while connective tissue is formed at the periphery, so that the *tubercle* comes to consist of a *caseous centre* (Fig. 459, *a*) and a *fibrocellular periphery* (*b*) which usually contains *giant-cells*. Under certain conditions the caseation may involve the entire tubercle. If the caseation does not affect the periphery, the fibrocellular tissue of the peripheral zone, sooner or later, becomes transformed into a pure *fibrous tissue*, so that a **fibrocaseous tubercle** (Fig. 460, *a*, *b*) is formed, the connective tissue of which is coarsely fibrillar or hyaline and poor in cells (*b*), and in the course of time usually becomes sharply defined from the caseous centre (*a*), so that the latter appears to be encapsulated by connective tissue. If the tuberculosis runs a favorable course the centre instead of caseating may undergo a connective-tissue metamorphosis (Fig. 461, *b*, *c*, *d*), so that the tubercle becomes changed into a **fibrous nodule**.

The *infectious nature* of the disease known as *tuberculosis* had already been determined by the experimental transmission of tuberculosis to animals (Villemin, Lebert, Wynn, Cohnheim, Klebs, Langhans, and others), before the discovery of the tubercle-bacillus. Nevertheless, it was a long time before the view that tuberculosis was an infectious disease received general acceptance, and opposition to this view has even to-day not wholly disappeared (Middendorp).

The peculiar behavior of the tubercle-bacillus toward stains—that is, its property of retaining the stain after treatment of the preparation with acids and alcohol, the so-called *acid- and alcohol-resistance*—makes it possible to demonstrate with relative ease the presence of tubercle-bacilli in the sputum or in the tissues, and to differentiate it from other bacteria. It should be noted, however, that other bacteria show these properties; the bacillus of leprosy, the *smegma-bacillus* (a bacillus very frequently found on the corona glandis, between the scrotum and thigh and in the folds between the labia majora and minora), further two different bacilli found in butter (one described by L. Rabinowitsch and Petri, the other by Korn), and finally also different bacilli cultivated by Moeller from grasses (timothy-grass) and from *con-dung*. All these acid-resisting bacilli may under certain conditions lead to errors of diagnosis; for example, the smegma-bacillus in the examination of urine, the butter-bacilli in the examination of butter, the latter particularly, since the bacillus described by Rabinowitsch, when injected into the peritoneal cavity of guinea-pigs, causes a disease of the abdomen similar to true inoculation-tuberculosis, while the bacillus described by Korn causes a pseudotuberculosis in white mice (these animals showing but slight susceptibility to true tuberculosis).

Since the tubercle-bacillus in cultures forms simple and branching threads (Klein, Fischel, Coppen-Jones, Nocard, Maffucci, and others) and bud- and club-like swellings, many authors are inclined to group it with the thread-fungi. Lehmann and Neumann designate it as *Myobacterium tuberculosis*, Coppen-Jones as *Tuberculomyces*.

Since the tubercle-bacillus in caseous pulmonary foci (Coppen-Jones), and after direct injection into the parenchyma of the brain, kidneys, mammary glands, and testicles, as well as after the intra-arterial injection of large numbers of bacilli (Babe, Levaditi, Schultze, Lubarsch, Friedrich, and Nasse) forms, in addition to the ordinary colonies of bacilli, fungus-masses also resembling those of actinomyces, on the outer surface of which ray-like clubs radiate into the surrounding tissue, Lubarsch and others, in the assumption that the fungus-masses consist of branching threads, have classed the

tubercle-bacillus with the actinomyces or ray-fungi. *Lubarsch* regards the ray-fungi as a sub-class of the *Streptothrices*, an intermediate group lying between the *Schizomyces* and the *Hyphomycetes*, and characterized by the formation of clubs; and to this class he assigns also the butter- and dung-fungi mentioned above. According to *Friedrich* and *Nöske* the fungus-masses regarded as resembling those of actinomyces consist only of rods.

According to the investigations of *Hammerschlag*, *Ruppel*, *Sata*, and others, the tubercle-bacilli contain an abundance of fat, which under proper conditions may be demonstrated by staining with sudan (*Sata*). According to *Hammerschlag* the tubercle-bacilli contain twenty-seven per cent. of substances soluble in alcohol and ether (fats, lecithin, poisonous substances), while other bacteria contain only 1.7-10 per cent. of the same. The remaining substance insoluble in alcohol contains albumin and cellulose.

According to the investigations of *Prudden*, *Hodenpyl*, *Kostenitsch*, *Vissmann*, *Masur*, *Kockel*, and others, dead tubercle-bacilli, when introduced into the tissues of an animal by inoculation, or injection into the blood-stream, or through introduction into the respiratory passages, excite, at the point of deposit, inflammation and tissue-proliferation similar to that caused by living bacilli, and in the case of a large inoculation may lead also to suppuration. These changes differ, however, from those produced by living bacilli, in that the bacilli are destroyed after a few weeks and the nodules of granulation tissue heal through a transformation into fibrous tissue; and further, by the fact that the severity of the local tissue-proliferation is dependent wholly upon the amount of dead bacilli introduced, and that there is no spread of the process throughout the body. The dead bacilli must therefore contain substances (proteins) which cause inflammation and later also tissue-proliferation.

In addition to the local effects, the substance contained in the cell-bodies of the bacilli may also cause emaciation of the animal.

The active substance of the bodies of the bacilli—*tuberculin*—was first produced by *Koch* (1890) from six- to eight-weeks-old cultures in a weak alkaline veal-infusion, to which one per cent. of peptone and four to five per cent. of glycerin were added, by evaporation upon a water-bath to one-tenth of the original volume and filtering through a filter of earthenware and silicious marl. Later (1897) he dried highly virulent cultures of tubercle-bacilli in a vacuum-exsiccator, then triturated the dry substance, mixed it with distilled water and centrifugated it. The active principle is contained in the muddy precipitate thus obtained, which is again dried and triturated and dissolved in water to which twenty per cent. of glycerin is added for the purpose of preservation. This tuberculin (designated by *Koch* as T. R.) is said to contain 10 mgm. of solid substance in 1 c.c. (prepared by *Meister*, *Lucius*, and *Brünning*).

*Tube*, by treating tubercle-bacilli killed by heating, with alcohol, ether, potassium hydroxide, and the Schweizer reagent (copper oxide-ammonia, solvent of cellulose), obtained three substances: *fat*, an albuminous body which he called *tuberculo-mycoprotein*, and a substance whose chemical nature was not definitely determined, which he called *tuberculo-bactericidin*.

Mycoprotein, when injected subcutaneously, causes a collection of leucocytes; large doses kill guinea-pigs in two to four days. Tuberculo-bactericidin also causes local inflammation; but is less poisonous for the organism as a whole.

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§ 167. **Tuberculosis** is at the beginning a **local disease**, which occurs most frequently in the lungs, intestinal tract, and skin; that is, in places accessible from without. *Cases of cryptogenic infection* are by no means rare; in these the first demonstrable disease-changes appear in tissues concealed in the deeper portions of the body-parenchyma—as, for example, in the lymph-glands, adrenals, bones, joints, brain, tubes—and it is to be assumed that under certain conditions the bacilli enter the body without causing lasting changes at the point of entrance, so that they develop first in some distant organ to which they are carried by the blood or lymph, and through multiplication give rise to tissue-proliferation and to emigration of white blood-cells.

The **local disease** usually begins with the formation of **miliary tubercles**—that is, cellular nodules of the kind described above—which arise in the tissue either singly or (in case of multiple infection) in great numbers simultaneously, or one after another (secondary dissemination of the multiplying bacteria). The tissue in the neighborhood of the individual tubercles, as well as that between the tubercles, shows some-



times a more, sometimes a less pronounced appearance of inflammatory exudation and proliferation of an especially cellular type; and through these processes there are frequently formed **large granulation-areas** in the infected connective tissue.

In the case of a *surface colonization of the bacilli*, as is possible in the alveoli of the lung and in the smallest bronchioles, an **exudative catarrhal inflammation** may be the first sign of the infection, while proliferative processes in the connective-tissue stroma and in the pulmonary vessels appear only at a later period.

In the mucous membranes and in the skin (Fig. 462) large areas of the mucosa and submucosa, or corium respectively, may through the



FIG. 462.—Lupus of the skin with atypical growth of epithelium, from the region of the knee (alcohol, hæmatoxylin, fuchsin, picric acid). *a*, Corium converted into granulation tissue in which there are scattered tubercles; *b*, epidermis; *c*, epithelial plugs growing into the deeper tissues; *d*, tubercle.  $\times 50$ .

formation of such granulations undergo a nodular or a diffuse flattened thickening. In the serous membranes there may develop large, flattened nodules in whose neighborhood the serosa is thickened and covered with a fibrinous exudate. In the synovial membrane of the joints and bursæ there often arise soft, spongy proliferations, the so-called *fungous granulations* (Fig. 463); in the periosteum and bone-marrow round, grayish-red, or gray granulation-areas of varying size appear. All these areas have one feature in common—namely, in their neighborhood are found inflammatory infiltrations and proliferations of tissue, which bear the character of a **granulation tissue** (Fig. 462, *a*; 463, *b*) inclosing characteristic non-vascular, cellular nodules—**tubercles** (Figs. 462, *d*; 463, *c*)—which often contain giant-cells. In grayish-red tissues rich in blood the tubercles may often be recognized by the naked eye as gray, or, when undergoing caseation, as white or yellowish-white nodules.

The area of *tuberculous granulation tissue* when once formed becomes larger in its further course of development by an *appositional growth*,





FIG. 463.—Tuberculous granulation tissue from the synovial membrane of the knee-joint (Müller's fluid, Bismarck brown). *a*, Connective tissue; *b*, granulation tissue; *c*, tubercle.  $\times 80$ .

dense fibrous tissue (Fig. 466, *a*, *b*) which in part shows a nodular arrangement (*a*), and in part is more hyaline and homogeneous in character. In the lungs such connective-tissue nodules contain more or less carbon-pigment (Fig. 466).

A second form of termination is a **combination** of **caseation** and **fibrous induration** comprising dense fibrous tissue (Fig. 467, *b*, *d*) and caseous foci (*a*) of varying size.

The third termination consists essentially in **caseation**, the tubercu-

whereby the same processes, as just described, consummate themselves at the periphery. There may arise in this way, either within an infected organ, or upon the surface of such, nodules of large size, **solitary tubercles** (Fig. 464, *c*) as, for example, in the pia, brain, and upon the dura mater, which not infrequently resemble true tumors, sarcomata in particular. Further, the tissue transformed by the tuberculous process or the newly formed tissue respectively, may suffer various fates; and there may be distinguished three chief forms of termination, which may, however, be combined in various ways.

In a first group of cases the production of connective tissue forms the most striking feature, and there results a **connective-tissue** induration of the diseased tissue (Fig. 465) with the development of a dense, fibrous connective tissue (*a*). If the process does not come to a standstill, there may be found in association with the fibrous tissue new *proliferations of granulation tissue* (*b*), and often also a larger or smaller number of typical *tubercles* (*c*). If the process comes to a complete **standstill** and to a **cure of the infection**, the entire area may come to consist of a

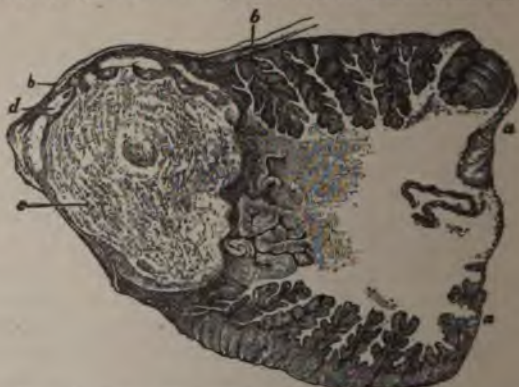


FIG. 464.—Large solitary tubercle of the pia mater of the cerebellum in vertical section. *a*, Cerebellum; *b*, dura mater adherent to the tubercle; *c*, laminated tubercle; *d*, gray peripheral zone adherent to the dura mater and beset with yellowish-white, nodular deposits. Natural size.

lous granulation tissue dying and producing no connective tissue at all, or only in such a slight amount that it is completely overshadowed by the caseous masses (Fig. 468).

Both the fibrocaseous and the purely caseous areas may become



FIG. 465.—Tuberculous induration of the lung (alcohol, hæmatoxylin, and eosin). *a*, Dense, fibrous tissue; *b*, cellular granulation tissue; *c*, giant-cells.  $\times 40$ .

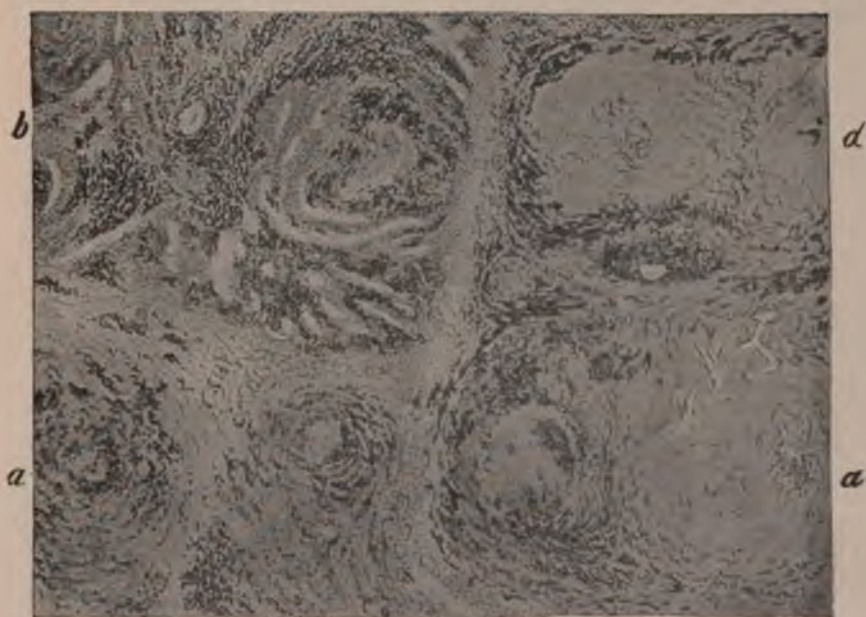


FIG. 466.—Tuberculous induration of the lung (alcohol, hæmatoxylin, eosin). *a*, Homogeneous fibrous nodules poor in cells and in part pigmented; *b*, diffuse induration of the lung.  $\times 24$ .



healed, through their *encapsulation* from the surrounding tissues by connective tissue (Figs. 467, *b*; 468, *c, e*). Such a healing can be regarded as complete only when in the connective-tissue capsule (Fig. 468, *c, e*) and

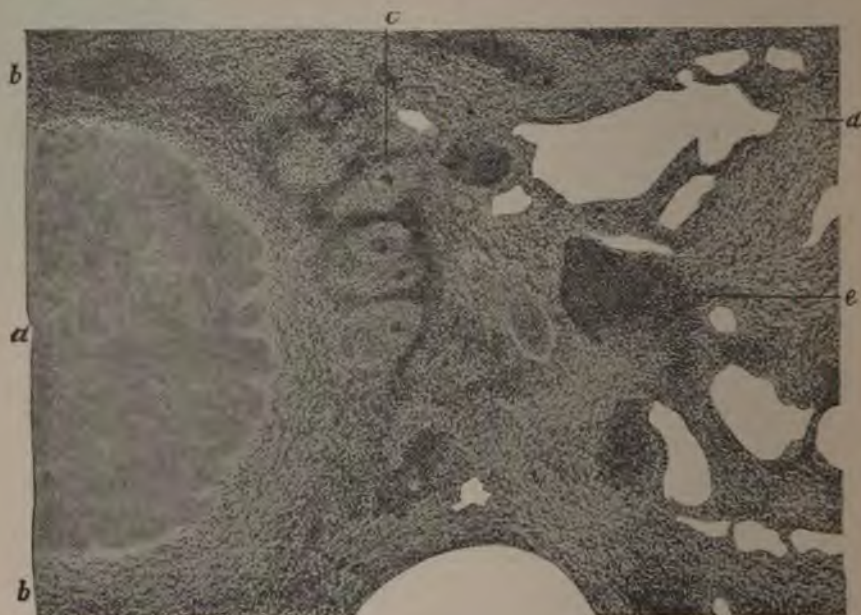


FIG. 467.—Encapsulated area of caseation of the lung with induration and eruption of tubercles in the neighborhood (formalin, alcohol, hæmatoxylin, eosin). *a*, Caseous area; *b*, fibrous capsule; *c*, tubercle; *d*, indurated lung tissue; *e*, area of granulation tissue.  $\times 40$ .

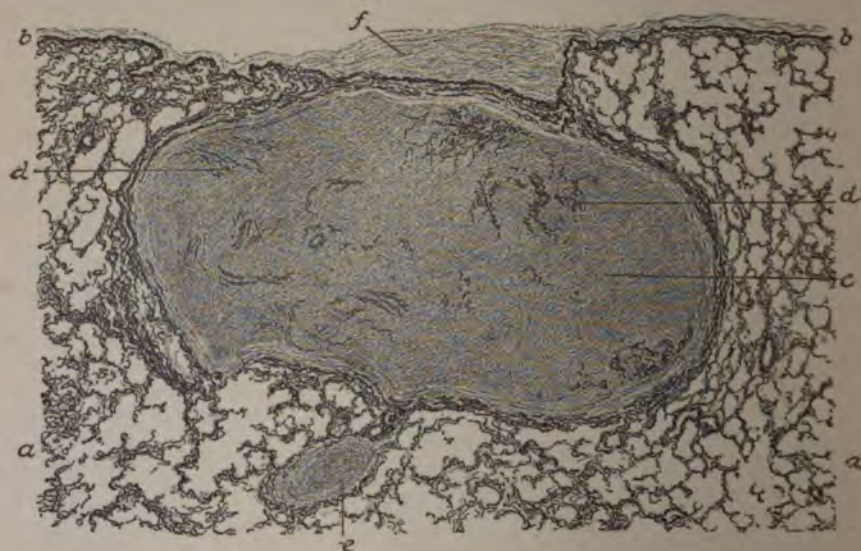


FIG. 468.—Encapsulated area of tuberculous caseation in the lung. *a*, Normal lung tissue; *b*, pleura; *c*, area of caseation; *d*, remains of elastic fibres in the area of caseation; *e*, small encapsulated caseous nodules; *f*, thickened pleura.  $\times 15$ .



its neighborhood (*a*) neither fresh granulation-tissue areas nor tubercles are still present. Occasionally **calcification** of the encapsulated caseous mass may occur as a further sign of the termination of the process.

The **caseous masses** of tuberculous foci are sometimes firm, sometimes soft, and in the latter case very often suffer a **disintegration** and **liquefaction** leading to the formation of milk-white, crumbling, and pul-taceous or even thin fluid masses, so that the tuberculous area comes to present the picture of an **abscess** surrounded by a wall (designated as *cold abscess*). Rupture and emptying of the same externally leads to the

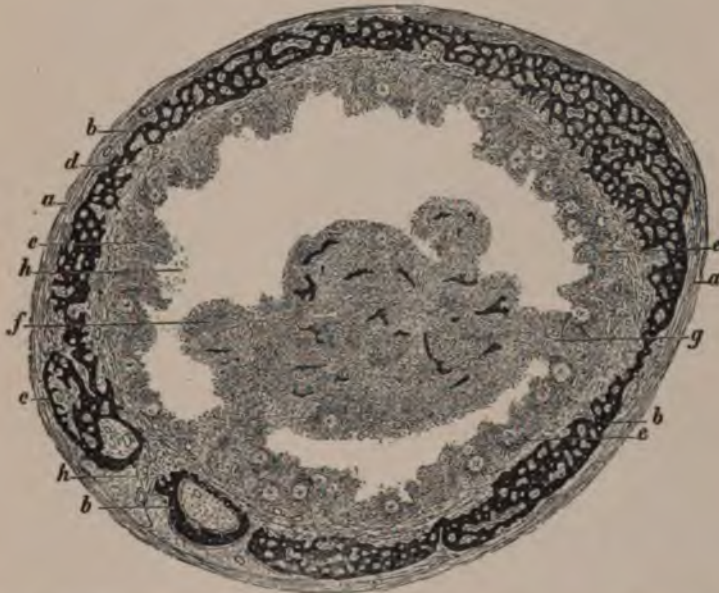


FIG. 469.—Tuberculous cavern in the tibia (alcohol, picric acid, hæmatoxylin, carmine). Transverse section. *a*, Periosteum; *b*, rarefied cortex; *c*, periosteal deposit of bone; *d*, fibrous tissue on the inner surface of the cortex; *e*, granulation tissue containing tubercles; *f*, sequestrum with bony trabeculae, infiltrated with granulation tissue; *g*, union of the granulation tissue with the sequestrum; *h*, cavity that had been filled with pus and caseous masses.  $\times 35$ .

formation of **cavities** or **caverns** and **fistulous passages** accessible from without, and, when there is a wide opening, to **ulcers**.

*Disintegration and cavity-formation* occur particularly in the lung, and may there lead to the formation of cavities as large as a man's fist or larger. They also occur not infrequently in caseating lymph-glands, and in caseous foci in the kidneys, brain, muscles, skin, and bones (Fig. 469). The cavities (*h*) contain in the beginning the liquefied tuberculous tissue, in which not infrequently remains of the original tissue may be recognized in the form of sequestra (*f*). After the evacuation of the contents the wall may furnish material sufficient to fill the cavity again either through the secretion of pus or through the breaking-off of necrotic tissue. *Hæmorrhages* not infrequently arise through the erosion of blood-vessels.

The *walls of the caverns and abscesses* are usually lined by caseating granulation tissue containing tubercles (Fig. 469, *e*); the surrounding tissue becomes indurated in part, and in part the seat of caseating foci.

Ulcers occur most frequently in the mucous membranes (Fig. 470, *h*) and in the skin, since the softening caseous masses in these regions most



FIG. 470.—Tuberculous ulcer of the intestine with eruption of tubercles in the neighborhood (alcohol, Bismarck brown). *a*, Mucosa; *b*, submucosa; *c*, muscularis interna; *d*, muscularis externa; *e*, serosa; *f*, solitary follicle; *g*, mucosa infiltrated with cells; *h*, ulcer; *h*<sub>1</sub>, area of softening; *i*, recent; *t*, caseous tubercle.  $\times 30$ .

frequently break through to the surface. The edges and base of the ulcers are surrounded by an inflammatory zone of infiltrated granulation tissue, often also containing tubercles.



FIG. 471.—Beginning tuberculous pneumonia of the lung without catarrh (alcohol, orcein). *a*, Caseous area with remains of elastic tissue; *b*, normal lung tissue; *c*, pleura with tubercles; *d*, *e*, tubercles in the neighborhood of the caseous area; *f*, tubercle in the pleura; *g*, periarterial; *h*, peribronchial; *i*, perivenous tubercles of the lymph-vessels; *k*, new-formation of fibrous tissue beneath the limiting elastic layer of the pleura.  $\times 16$ .



If a tuberculous focus does not become healed through tissue-induration, sequestration or encapsulation of the dead tissue, or through the removal or death of the bacilli, there exists the **danger of metastasis**.

This takes place first by the lymph-channels; and a part of the pict-



FIG. 472.—Beginning tuberculosis of the lung in a two-year-old child. Horizontal section through the right lung (Müller's fluid, carmine). *a*, Caseous area in the region of the anterior border; *b*, posterior inner border free from tubercles; *c*, transverse section of the bronchus; *d*, *d*<sub>1</sub>, caseating lymph-glands; *e*, pulmonary vein; *f*, point where the vein *e* has become adherent to the lymph-gland *d*<sub>1</sub>; cheesy degeneration of the vein-wall has also begun at the same point; *g*, tubercles in the lymph-vessels of the pulmonary parenchyma; *h*, periarterial, *i*, peribronchial, *k*, perivenous, *l*, pleural tubercles; *m*, tubercle of lymph-vessel at hilum of the lung.  $\times 2\frac{1}{2}$ .

ure of a progressive tuberculosis is the development of tubercles in the lymph-spaces and in the walls of the lymph-vessels (Figs. 470, *i, i*; 471, *e, f, g, h, i*; 472, *g, h, i, k, l, m*) in the neighborhood of the primary focus. The lymphogenous miliary tuberculosis is in some cases limited

to the immediate neighborhood of the primary focus (Fig. 471), at other times it involves larger areas and may, for example, extend from a caseating tubercle in the lung (Fig. 472, *a*) over a large part of the pulmonary lymphatic system. These lymphangiotic tubercles present the appearance of bright gray nodules, often surrounded by a red zone, and consist essentially of the same structure as the primary focus.

The lymph-glands may be affected very early (Fig. 472, *d, d*), whereupon tubercles develop in them (Fig. 473, *a, a*), leading through successive crops of the same to

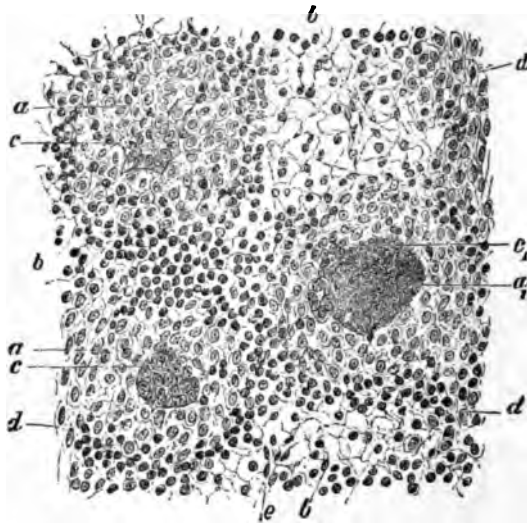


FIG. 473.—Eruption of tubercles in a lymph-gland (alcohol, hæmatoxylin). *a*, Tubercle; *a*<sub>1</sub>, caseous tubercle; *b*, tissue of the lymph-gland; *c*, giant-cell in the centre of a tubercle; *c*<sub>1</sub>, giant-cell at the edge of a caseous focus; *d*, large-celled tissue between the tubercles; *e*, blood-vessel.  $\times 150$ .

a more or less marked enlargement and finally to a caseation of the glands (Fig. 472, *d, d*), or to an induration, or to a combination of these processes. The thoracic duct may become infected from caseating and disintegrating lymph-glands, and through this channel an infection of the blood may also take place.

Very often the formation of metastases takes place also through the blood-stream; in the first place by the entrance of bacilli through the lymph from the thoracic duct as mentioned above, but very often also as the result of the direct entrance of bacilli into the circulating blood. In tuberculous tissue the bacilli may pass directly into small veins, though the obstruction to the circulation due to the closure of the vessels usually prevents their further dissemination. Often enough the bacilli gain entrance into the larger veins—as, for example, through the adhesion of caseating lymph-glands at the hilum of the lungs (Fig. 472, *d*<sub>1</sub>) with the neighboring veins (*e, f*), the tuberculous process involving the vein-walls by direct extension. Moreover, an infection of numerous veins with tubercle-bacilli may occur in the neighborhood of a tuberculous focus, so that the small veins of an entire vascular system may present a well-marked tuberculous disease—that is, an inflammatory granulation-proliferation of the vessel-walls with the formation of tubercles and subsequent caseation (Fig. 474, *b*), so that, if thrombosis does not occur, large numbers of bacilli may enter the blood-stream from the diseased walls. In rare cases the arteries, particularly the pulmonary arteries, may become tuberculous through infection from the surrounding tissues, and so may give off bacilli to the blood-stream.



The transportation of the bacilli through the blood-stream gives rise to a **hæmatogenous miliary tuberculosis**—that is, to an eruption of miliary tubercles (Fig. 475, *a*) at those places where the bacilli become lodged and multiply. Just where these places will be, and how numerous the tubercles, depend upon the location of the point of rupture and the number of bacilli entering the blood. The entrance of many bacilli into the blood may lead to a *general hæmatogenous miliary tuberculosis*.

If the bacilli have entered the blood-stream in small numbers and have been deposited in only one organ, and if death does not ensue, there arises in this organ a progressive *hæmatogenous local tuberculosis*, which runs a course similar to that of the primary focus coming from without.

The *inflammation accompanying the hæmatogenous eruption of tubercles* is sometimes more, sometimes less pronounced, and is usually most severe in the meninges and in the lungs.

Should a tuberculous focus in the lung break into the bronchi, as the result of the softening of a caseous area, or if a caseating focus in the kidney should invade the kidney-pelvis, there will result a *dissemination of tubercle-bacilli over the surface of the mucous membranes*. From the bronchi the bacilli spread into the trachea, larynx, mouth-cavity, and thence into the alimentary canal; through aspiration during deep quick inspiration, they may be carried into other portions of the lungs as yet

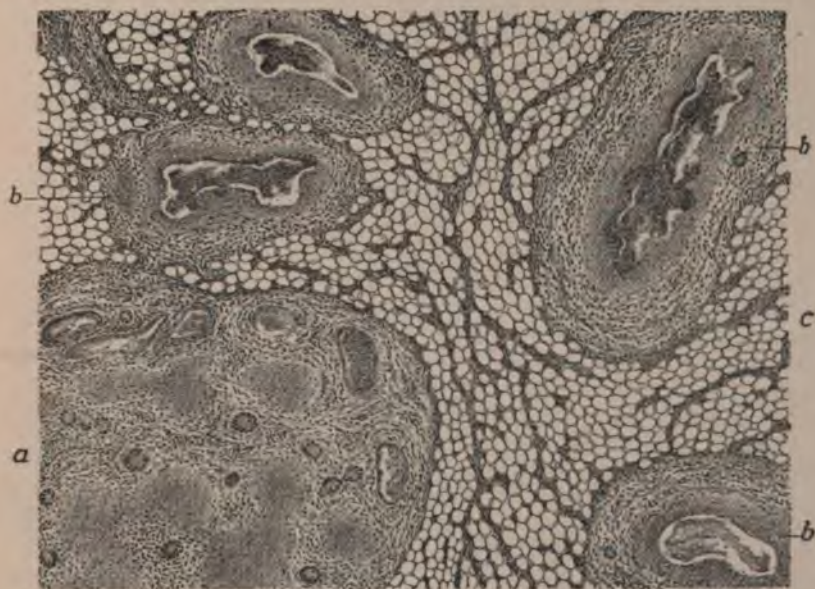


Fig. 474.—Tuberculosis of the veins in the neighborhood of a tuberculous retroperitoneal lymph-gland (formalin, hæmatoxylin, eosin). *a*, Tuberculous lymph-gland with giant-cells and caseous foci; large blood-vessels at the periphery; *b*, veins whose walls are thickened by tuberculous granulation tissue, the inner layers of which show caseation; *c*, fat tissue.  $\times 28$ .

unaffected. From the kidneys the bacilli may be spread throughout the descending urinary passages.

A *secondary infection* may also result from this spreading of the bacilli, yet only a small percentage of the bacilli thus distributed give rise to an infection; and experience has taught us that only certain portions of the mucous membranes are susceptible to infection—particularly

the tonsils and the lymphadenoid tissue of the small and large intestines, while the œsophagus and stomach are almost immune; and in the case of the descending urinary passages, the kidney-pelvis, the ureters, and bladder are usually infected while the urethra almost always remains uninvolved.

If bacilli enter the great body-cavities they can also spread over the surfaces of the serous membranes, infect the latter, and excite a diffuse inflammation and formation of nodules (Fig. 476). A new-formation of connective tissue may follow later.

Should tubercle-bacilli be present in the circulating blood of a woman during pregnancy, the infection of the placenta and fœtus may follow, so that the child will be born already infected. In so far as data concerning this point exist, this event is not of frequent occurrence; and it is more usual for

FIG. 475.—Hæmatogenous miliary tubercles of the liver (alcohol, carmine). a, Developed tubercle in the connective tissue about the portal vein; b, collection of leucocytes.  $\times 150$ .

children of tuberculous parents to become infected after birth. A conceptional infection of the embryo through infected semen has not yet been demonstrated, and is very unlikely.

**Secondary infections** are not infrequently associated with that caused by tubercle-bacilli, and this occurs particularly when the disintegration-cavities or ulcers are accessible from without. Secondary infections of tuberculous lungs are of very frequent occurrence, and are due particularly to streptococci and staphylococci, pneumococci, influenza-bacilli, micrococcus tetragenus, and bacterium coli. Many authors are inclined to refer all severe inflammatory exudations accompanying pulmonary tuberculosis to such secondary infections; but this is not correct in so far that the formation of tubercles by tubercle-bacilli may be accompanied by inflammatory exudations of such severity that



FIG. 476.—Tuberculosis omentum (Müller's fluid, carmine). a, Centre of tubercle; b, cells of epithelioid character; c, lymphatic elements; d, proliferating epithelium (endothelium) in the neighborhood.  $\times 300$ .



serous or serofibrinous, or pure fibrinous, or fibrinopurulent exudates may collect in large quantities in the tissues (in the pulmonary alveoli, on the pleura, and in the subarachnoidal space, etc.). A high (septic) fever, rapid destruction of tissues with a tendency to suppuration, and an unusually severe inflammation, in part of a hæmorrhagic character, point to a secondary infection. Nevertheless, it is often impossible to determine, without a special investigation directed to this point, whether a pure tuberculosis or a mixed infection is present.

For the treatment of tuberculosis with bacterial extracts and curative serum see § 32.

The question as to how often **tuberculosis is transmitted by the passage of bacilli from the mother to the child** is still an open one. It has, however, been shown by *Schmolt*, *Birch-Hirschfeld*, and *Landouzy* that in cases of miliary tuberculosis in pregnant women, tubercle-bacilli are present both in the intervillous spaces and in the blood of the chorionic vessels, and that the liver of the fœtus may contain bacilli. Further, cases of tuberculosis of the placenta also occur (*Schmolt*, *Kockel*, *Langreitz*), which may be regarded as stages on the way of the tubercle-bacillus from the mother to the fœtus.

Cases of tuberculosis occurring at an early period of life, reported by *Denme*, *Baumgarten*, *Rilliet*, *Charrin*, and others, as well as the statements of *Armanni*, *Landouzy*, and *Martin*, that the inoculation of portions of the organs of human fœtuses obtained from tuberculous mothers produced tuberculosis in guinea-pigs, speak in favor of a passage of tubercle-bacilli from the mother to the fœtus. Still more important are the experimental investigations of *de Renzi* and *Gärtner*, who succeeded through the inoculation of pregnant guinea-pigs, white mice, and rabbits in producing tuberculosis in a part of the young born of these animals. *Gärtner* is consequently of the opinion that under certain conditions tubercle-bacilli may pass from the mother to the fœtus in the case of both animals and man. Finally, *Maffucci* and *Baumgarten* succeeded in effecting a transfer of tubercle-bacilli to impregnated hen's eggs, and discovered that the infection did not disturb the development of the chick, but, on the contrary, the bacilli that were taken up by the embryo remained in the tissue of the latter without multiplying to any extent, later to cause a tuberculosis in the body of the hatched-out chick. According to the investigations of *Friedmann* tubercle-bacilli deposited at the same time with semen, in the vagina of rabbits, gained entrance into the embryo and could still be demonstrated on the sixth day.

The experiments cited above not only justify the assumption that bacilli may be transferred from the mother through the placenta to the child, but also that they may remain in the body of the embryo for a long time without causing specific changes. The occurrence of a conceptional tuberculosis through the transmission of bacilli in the semen is still a question. It must be noted, however, that the semen and the contents of the seminal vesicles often contain tubercle-bacilli, not only in cases of tuberculosis of testicle and epididymis, but also in cases in which no tuberculous affection of the sexual apparatus could be demonstrated. In general, the following principles may be summed up: *Tuberculosis is usually to be referred to an extra-uterine infection*; and the children of tuberculous parents suffer so frequently from this disease, because they are more exposed to infection with tubercle-bacilli than are the children of healthy individuals. A special predisposition of the children of tuberculous parents to tuberculosis has not been demonstrated.

In animals a transmission of tuberculosis to the fœtus seems occasionally to occur, according to the reports of *Zippelius*, *Jensen*, *Patz*, *Grothaus*, *Malvoz*, *Lydtin*, *Brouquier*, *Adams*, and others. *John* was not only able to demonstrate in a foetal calf the presence of miliary nodes and larger nodules in the lungs, liver, and various lymph-glands, but also to show the presence of characteristic bacilli in the lesions.

From the side of clinicians and physicians the so-called **scrofula** has been many times regarded as an especial pathological condition of the organism of the child, predisposing it in an especial degree to tuberculosis. As scrofulous are regarded those children who permanently or at least very frequently suffer from inflammations of the mucous membranes, nose and its accessory cavities, conjunctiva, middle ear, as well as of the skin, also from swelling of the lymph-glands leading occasionally to necrosis and suppuration, finally also from chronic inflammations of the bones and joints, and who present a flabby, pale, often bleated appearance. In many cases these symptoms are due to tuberculosis, in other cases they are caused by an infection with streptococci or staphylococci, or are the results of syphilis. Scrofula is not a disease entity, but is only an especial symptom complex belonging to different diseases. Whether the affected

children possess an *especial predisposition to all these infections* which may be designated as *scrofula* is difficult of proof. The organism of the child is in general easily infected by these agents, and the frequent illness of certain children due to these infections may be referred to a lack of cleanliness, or to especial conditions of the environment of the child, or to frequent injuries, etc., as well as to an especial predisposition of the child itself.

**Tuberculosis of mammals** is observed most frequently in the case of *cattle*, and presents in general a course similar to that of the disease in man, though the granulation-areas develop more frequently into larger tumor-like nodules, particularly so in cattle, and the tendency to a generalization of the disease is less. The tuberculosis of the serous membranes which is often designated as **pearl disease** ("*Perlucht*") begins with the formation of small nodules, leading then to a more marked proliferation of the connective tissue, giving rise to the formation in the thickened serosa of nodules of the size of a pea or bean or even as large as a hen's egg or man's fist (Fig. 477), which in the beginning are soft and sarcoma-like, but later become firmer and denser and often enclose calcified areas of caseation. The form of the proliferation is sometimes villous-

like and warty, at other times of a mulberry- or grape-like form, cauliflower-like or even polypoid.

Next to cattle the *hog* is most frequently affected with tuberculosis, more rarely the horse, goat, sheep, cat, and still more rarely the dog.

Of *wild animals* in captivity, the ape, lion, tiger, bear, jackal, panther, jaguar, giraffe, and dromedary easily acquire tuberculosis. Of the small animals used for experiment the guinea-pig is the most susceptible. After subcutaneous inoculations there results a progressive tuberculosis which kills the animal in from about four to eleven weeks. In rabbits an inoculation tuberculosis may heal. Field mice and white mice are infected with difficulty.

Tuberculosis is of frequent occurrence in **birds** (chickens, pigeons, pheasants, and parrots), but the bacillus of avian tuberculosis is not identical with that



FIG. 477.—Growths from the pleura in a case of bovine tuberculosis ("*Perlucht*").

of mammalian tuberculosis (*Maffucci*, *Rirolta*, *Straus*, *Gamaleia*, *Baumgarten*, *Roger*, and others); the tuberculosis of parrots alone is in great part caused by the bacillus of mammalian tuberculosis.

The cultures of tubercle-bacilli from man are dry, warty, or scaly and lustreless; those of avian tuberculosis moist, wrinkled, and soft, and moreover grow best at 43° C. Dogs are wholly immune to avian tuberculosis, but not to human tuberculosis. The intraperitoneal inoculation of mammalian tuberculosis (*Leray*) causes in rabbits numerous caseous foci in the liver and spleen with few giant-cells and scanty bacilli, and in the lungs numerous caseous nodules containing numerous bacilli. Inoculations into these animals of chicken-tuberculosis, on the other hand, cause a scanty production of non-caseating cellular proliferations containing giant-cells and great numbers of bacilli.

According to *Maffucci*, *Martin*, and *Gärtner*, the inoculation of human tuberculosis into chickens does not produce tuberculosis, but the bacilli remain alive for weeks within the body of the chicken. Pigeons (*Lacclair*) die after intraperitoneal inoculation, but no tubercles are found in the tissues; the liver and lungs may contain living bacilli fourteen days after the inoculation. In guinea-pigs (*Straus*) the bacilli of human tuberculosis cause much more severe changes than do the bacilli of chicken-tuberculosis. Whether man is susceptible to avian tuberculosis is still an open question.

As **pseudotuberculosis** may be classed all those affections characterized by the formation of cellular and fibrous nodules, and in part also undergoing necrosis, and which are similar to tubercles, but which are not caused by *Koch's* bacillus. According to the etiology the following forms may be distinguished:

1. **Pseudotuberculosis due to dead foreign bodies.** This may be caused by the experimental injection of lycopodium-spores, olive-oil, and mercury into the blood-vessels,



the inhalation of irritating material into the lungs, the injection of large quantities of milk into the peritoneal cavity, etc. The presence in the tissue of caterpillar hairs, pieces of wadding, silk threads, etc., cholesterin tablets from ruptured ovarian cysts, and stomach-contents which have gained entrance into the peritoneal cavity, etc., may also lead to the formation of fibrocellular nodules.

2. *Pseudotuberculosis caused by monomorphous and polymorphous bacteria.* Eppinger, Bucholz, and Flezner have described forms of *Cladothrix* and *Streptothrix* obtained from apparently tuberculous lungs and bronchial glands which they are inclined to regard as the cause of the disease. Courmont found in an apparently tuberculous elbow-joint a bacillus which was not identical with Koch's bacillus. An affection of the peritoneum resembling tuberculosis may be produced in guinea-pigs by the injection of the butter-bacillus of Rabinowitch (which probably comes from cow-dung) as well as by the grass-bacillus of Moëller; and in white mice by the inoculation of the butter-bacillus of Korn.

In the rodents a disease resembling tuberculosis is not infrequently produced by a plump, thick bacillus with rounded ends (Pfeiffer, Preisz, Zagari, Nocard, Bonome, Delbanc, and others). Other forms of bacillary pseudotuberculosis have been observed in rabbits (Eberth), in birds (Muir), in the cow (Courmont), etc.

3. *Pseudotuberculosis due to hyphomycetes* occurs in the lungs and may be produced artificially by the injection of different forms of aspergillus and mucor; but the affections so produced show peculiarities which make possible a differentiation from true tuberculosis.

4. *Pseudotuberculosis caused by animal parasites* occurs particularly in the sheep, hog, goat, cat, hare, roe, stag, and chamois, and is caused by different forms of *Strongylus* and by *Pseudalius capillaris* (Müller); it is therefore a vermin pseudotuberculosis.

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See also § 166.

§ 168. **Syphilis** is, like tuberculosis, an infectious disease, which, proceeding from a local infection, spreads throughout the organism by means of the blood- and lymph-channels, and leads to the formation of localized inflammations and proliferations of granulation tissue, which, however, do not present so characteristic a structure as does the tubercle.

As the cause of syphilis there was described by Lustgarten, in 1884, a *bacillus* which, it is possible, may have pathogenic significance and may represent the *contagium of syphilis*. The only point in favor of this assumption is the fact that the bacilli have been demonstrated in all stages of the most varied forms of syphilitic foci. The bacilli have not yet been cultivated.

The bacillus is similar to the tubercle bacillus, 3 to 7  $\mu$  long, often curved, and somewhat swollen at the ends. According to Lustgarten it may be made visible by a complicated staining-process, by which the sections are stained in aniline-gentian-violet solution, then decolorized in potassium permanganate, and washed in sulphurous acid. Other authors have more recently published other methods.

The bacilli are found in syphilitic foci only in small numbers, and lie for the greater part from one to four in a single cell (Lustgarten), but also between the cells, and are at times also present in the blood (Doutrelepont). The Lustgarten bacillus can hardly be used, at the present time, as an aid to differential diagnosis, since the *smegma-bacillus* found in the preputial secretion and in the smegma between the labia majora and the labia minora stains also by the method described by Lustgarten. According to Doutrelepont, Klempner, and Lewy, it is possible to distinguish these bacilli from one another by proper staining methods (carbol fuchsin).

The poison through whose inoculation syphilis is produced occurs only within the human organism, where it is alone reproduced; and is communicated to other individuals only by direct or indirect transfer. When implanted in an organism it excites inflammatory processes of

the most varied intensity and extent—from a simple local transitory hyperemia to the production of large exudates or tumor-like granulations, or extensive hyperplasias of connective tissue. If a child is be-

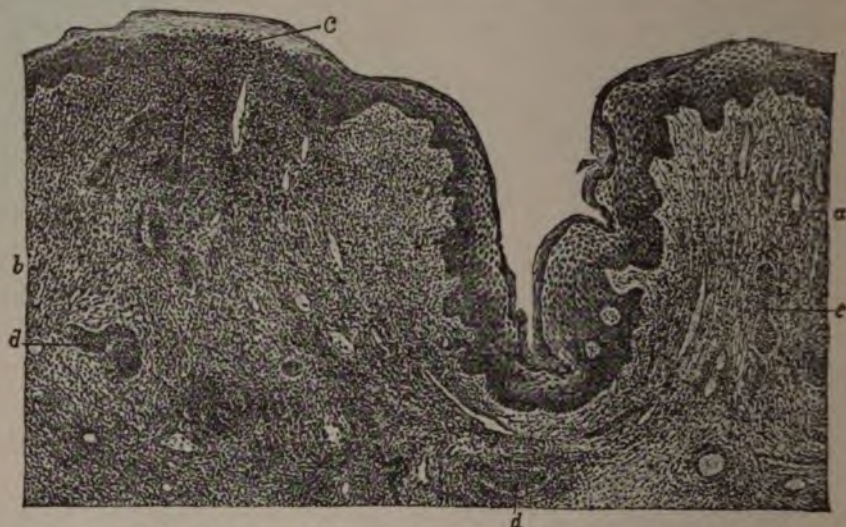


FIG. 478.—Initial sclerosis (alcohol, hæmatoxylin, eosin). *a*, Corium, slightly inflamed; *b*, initial sclerosis; connective tissue infiltrated with cells; *c*, rupture of the cells into the epithelium; *d*, *e*, lymph-vessels filled with leucocytes.  $\times 35$ .

gotten in the presence of a syphilitic infection, the disease may be transmitted to the fœtus by the father as well as by the mother.

If the first focus of inflammation develops at the point of infection, which is usually located in the skin or mucous membranes (mouth, throat, mucosa of genital apparatus), there is formed first a papule which spreads toward the surface, and within eight to ten days after its appearance forms scales, or ulcerates and secretes a small amount of

serous or purulent fluid which dries to a scab; at the same time its base becomes hardened and forms a thick disc-like or a thin parchment-like deposit in the skin. Occasionally a vesicle is also formed, and this becomes an erosion, and then an ulcer with scanty secretion and having an indurated base. In still other cases an ulcer is first formed, and the base becomes indurated subsequently.

The induration is called the **initial sclerosis** or the *Hunterian induration* (Fig. 478, *b*); the ulcer is known as a *hard chancre*. The former is caused essentially by a collection of small round cells (Figs.



FIG. 479.—Section from a syphilitic initial sclerosis (alcohol, alum carmine). *a*, Round-cell infiltration; *b*, large mononuclear formative cells; *c*, multinuclear formative cells.  $\times 350$ .

478, *b*; 479, *a*) in the spaces of the connective tissue. Occasionally epithelioid cells (Fig. 479, *b*) and isolated giant-cells are also formed (*c*).



With these changes the height of the process is reached; the greater part of the tissue disintegrates and ulcerates, or is absorbed after disintegration. A part of the cells are utilized in the formation of scar tissue.

Within the area of the initial sclerosis and its immediate neighborhood the lymph-vessels (Fig. 478, *d, e*) are dilated and filled with leucocytes. Later, after the lapse of a certain length of time the lymph-glands, the skin, and the mucous membranes become involved in inflammatory processes (symptoms of the secondary stage). Still later, there follow syphilitic inflammations of the internal organs and the bones (tertiary stage). These are in part like other non-syphilitic inflammations, but special forms of granulation tissue are sometimes produced. The syphilitic affections of the skin which are grouped under the term **syphilides** form sometimes only red spots, sometimes larger or smaller papillary elevations which may be associated with the formation of vesicles and pustules as well as with the production of scales. Accordingly,



FIG. 480.—Condyloma latum ani (alcohol, Bismarck-brown). *a*, Horny layer; *b*, mucous layer of the epidermis; *c*, corium; *d*, loosened horny layer infiltrated with small cells; *e*, swollen, *f*, swollen and infiltrated mucous layer; *g*, epithelial cells containing round cells; *h*, granular masses of coagula; *i*, swollen papillary body infiltrated with cells and fluid; *k*, corium, swollen, and infiltrated with cells, fluid and coagulated albumin; *l*, dilated lymph-vessels filled with clots; *m*, sweat-glands.  $\times 150$ .

the different forms of cutaneous syphilides have been called by different names, as follows: *Roseola syphilitica*, and *papular*, *vesicular*, *pustular*, and *ulcerative syphilides*, as well as a *psoriasis syphilitica* (*cf.* Pathological Anatomy of the Skin). A common element in all these affections is a more or less marked inflammation, which is characterized particularly by a tissue-infiltration and in part also by proliferation. Thus, for example, in the *large papular syphilide* or *condyloma latum* there is a beet-like elevation of the skin caused by an infiltration of the papillary body (Fig.

480, *i*), the corium (*k*), and also the epithelium (*e, f, g, h*) with cells and a fluid exudate which coagulates with the hardening of the tissue. If the horny layer of the epidermis becomes macerated, these masses of exudate may appear upon the surface, and give rise to a moist condition of the condyloma. In the pustular syphilides the inflammation leads to a puru-

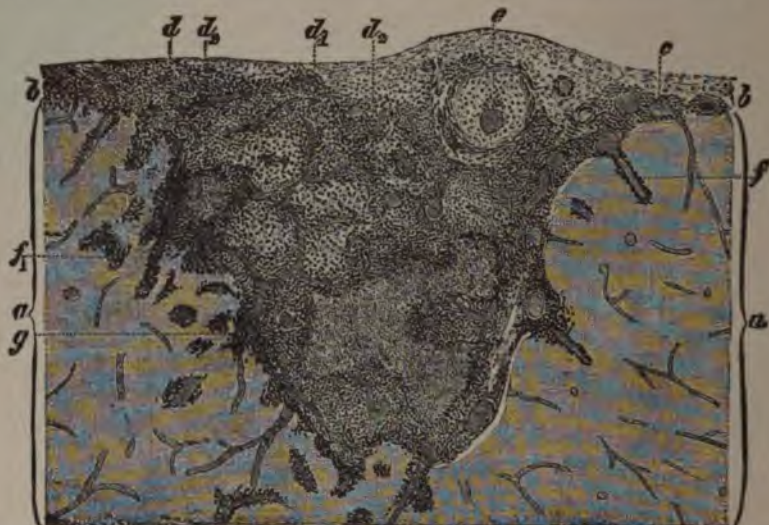


FIG. 481.—Meningo-encephalitis syphilitica gummosa (Möller's fluid, alum carmalum). *a*, Brain cortex; *b*, inner meninges; *c*, vein surrounded by cellular exudate; *d*, fresh cellular granulation tissue; *d*<sub>1</sub>, fibro-cellular granulation tissue; *d*<sub>2</sub>, cascated granulation tissue; *e*, artery with markedly thickened intima and adventitia infiltrated with cells; *f*, cellular infiltration of the pia-sheaths of the cortical vessels; *f*<sub>1</sub>, perivascular cellular infiltration of the cortical substance; *g*, diffusely spreading cellular infiltration invading the brain-substance.  $\times 14$ .

lent liquefaction of the epithelium, and in the ulcerating forms also of the papillary body and of the corium, so that *ulcers* result.

Inflammatory changes similar to those in the skin appear, in the secondary stage of syphilis, also in the mucous membranes, particularly of the mouth, throat, and respiratory passages.

The syphilitic lesions of the tertiary stage, appearing in the internal organs, in the glands, bones, muscles, subcutaneous and submucosal tissues, in the meninges of the brain, etc., in so far as they consist not only of slight degenerative and inflammatory processes or hyperplasias of connective tissue without characteristic features, appear as formations which are usually designated as **gummata** (Virchow). In its early stages the gumma, as well as the broad condyloma, represents an inflammatory process localized to one tissue-area; but the gumma is usually more rich in cells and not infrequently attains a higher degree of development in so far that a peculiar form of granulation tissue with new vessels (Fig. 481, *d, d*<sub>1</sub>) is formed. The gumma occurs particularly in the periosteum and membranes of the brain, as well as in the parenchymatous organs of the abdomen, especially in the liver, spleen, and in the testicles; and shows a difference in the abundance of its cells according to location. The forms which are poor in cells are observed chiefly in the bones; they are soft in consistence and on section present a gelatinous appearance, in that the fluid portion of the node is in excess of the cellular mass. The tissue also undergoes a partial metamorphosis into mucous tissue.



The gummata rich in cells are found especially in the inner meninges (Fig. 481), in the submucosa of different mucous membranes, in the skin, liver, testicles, and spleen; and form gray, or grayish-white or grayish-red, sometimes spherical (spleen, testicles), at other times more irregularly shaped, nodules (inner meninges), which in their light-gray or reddish-gray color and somewhat translucent character are similar to normal *granulation tissue*. Besides these lesions, diffuse inflammatory changes are often present in the affected organs.

Small syphilitic foci of infiltration often vanish quickly through absorption; in larger ones there occurs frequently a suppuration or a fatty and necrotic disintegration. The disintegration of syphilitic foci of the skin and subcutaneous tissue, as well as of the mucosa and submucosa, leads to the formation of **ulcers**, which, in the case of the mucous membranes, occur most frequently in the region of the mouth, throat, and the upper respiratory tract (Fig. 483, *a*). In the interior of deeper-lying gummata there are not infrequently formed caseous areas (Figs. 481, *d*; 482, *a*), which are at times regularly spherical, at other times irregularly shaped. The peripheral portions pass over into a scar-like connective tissue (Fig. 482, *b, c, d*) which encloses the caseous areas and radiates in bands into the surrounding tissues. In the neighborhood of

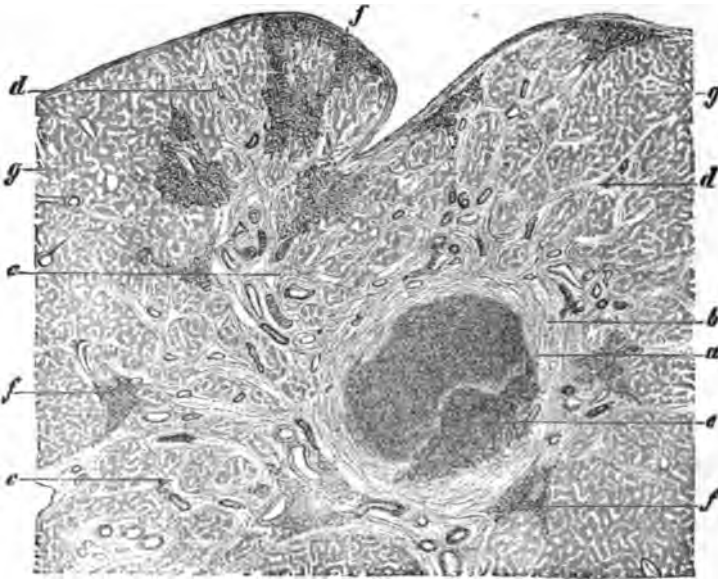


FIG. 482.—Gumma hepatis (alcohol, alum carmine). *a*, Caseous nodule; *b*, homogeneous connective tissue; *c*, connective tissue with remains of liver tissue; *d*, connective-tissue bands radiating into the liver tissue; *e*, cellular focus at the edge of the caseous nodule; *f*, cellular focus within the connective-tissue rays; *g*, liver tissue.  $\times$  12.

the ulcers arising in mucous membranes there are not infrequently formed *papillary proliferations* (Fig. 483, *b, c*).

Necrotic remains of gummata which originally were cellular come under anatomical examination far more frequently than those which are still perfect, and in this condition are usually still designated as gummata. Not only does the cellular new-formation take part in the devel-

opment of the gumma, but also the *infiltrated* tissue itself, in that the latter also *undergoes necrosis* and becomes *caseated*.

The cause of the frequent disintegration and necrosis occurring in syphilitic inflammations lies in the peculiar character of the exciting cause of the disease. A second factor may also be largely responsible for this manner of termination—namely, the extensive participation of the blood-vessels, particularly of the arteries, in the inflammation. When a syphilitic inflammation leads to the formation of granulation tissue or to a connective-tissue hyperplasia, the vessel-walls also become thickened, particularly the intima (Fig. 481, *e*), so that the vessel-lumen is narrowed and not infrequently completely closed. Occasionally the syphilitic process is localized chiefly in the vessels.



FIG. 483.—Syphilitic ulceration of the larynx. Sagittal section through the larynx and trachea. *a*, Ulcer; *b*, thickenings and papillary proliferations on the epiglottis; *c*, thickenings and papillary proliferations on the left wall of the larynx and the superior thyro-arytenoid ligament. Natural size.

Besides the peculiar foci of inflammation which point to a localization of the exciting cause of syphilis, there not infrequently occur in individuals who have suffered a syphilitic infection specific *degenerations of the central nervous system* (tabes, progressive paralysis), which are associated with proliferations of neuroglia. Nevertheless, these affections, though regarded as the *sequelæ of syphilis*, present histologically no peculiarities characteristic of syphilis, and occur in the same form in other individuals who have never had a syphilitic infection.

**Hereditary syphilis** is characterized chiefly by peculiar tissue-changes, which differ considerably from the manifestations of acquired syphilis, but changes also occur which correspond to the latter. In the skin hereditary syphilis may cause macular, papular, and pustular syphilides which may lead to ulceration. The spleen is usually more or less enlarged, and in individual cases may attain ten times its normal volume. In the liver there occur intravascular and perivascular collections of round cells which

often collect in small closely packed foci; associated with these there is a periportal new-formation of connective tissue. There is also a diffuse hyperplasia of connective tissue throughout the entire liver (Fig. 484, *a*, *b*), giving to the organ a firm consistence and a peculiar yellowish-brown color. Further, there is also a proliferation of connective tissue limited to the periportal tissue. The lungs may present, throughout or in part, a dense gray or grayish-white structure resembling that of sarcoma tissue. This appearance is due to the formation in the altered area of a cellular connective tissue (Fig. 485, *a*, *b*) which contains only imperfectly developed alveoli (*e*, *e*<sub>1</sub>) and bronchi (*d*, *d*<sub>1</sub>) or none at all. In cases of slight severity there exists only a thickening of the peribronchial and perivascular tissue and interalveolar septa, in part associated with an accumulation of desquamated epithe-



lium in the alveoli. In the kidneys and testicles the supporting connective tissue may likewise be increased in places, and abnormally rich in cells. *Syphilis* also often causes in glandular organs a pathological develop-



FIG. 484.—Induration of the liver in congenital syphilis (Müller's fluid, haematoxylin, eosin). *a*, Hypertrophic periportal connective tissue; *b*, indurated gland tissue infiltrated with connective tissue; *c*, collections of cells.  $\times 100$ .

ment of the connective-tissue elements and collections of cells, while the epithelial tissues are retarded in their development. In the blood the number of white corpuscles appears often to be increased. Finally,



FIG. 485.—Changes in the lung in congenital syphilis (Müller's fluid, haematoxylin, eosin). *a*, Proliferating stroma rich in cells; *b*, cellular granulation-foci; *c*, artery with thickened adventitia; *d*, *d*<sub>1</sub>, gland-like bronchi, which in part (*d*<sub>1</sub>) contain desquamated epithelium and round cells; *e*, *e*<sub>1</sub>, alveoli, which in part (*e*<sub>1</sub>) contain desquamated epithelium and round cells.  $\times 52$ .

there not infrequently occur in the bones disturbances of endochondral ossification, which are characterized chiefly by irregularity in the formation of the medullary cavity and in the deposit of lime-salts in the car-

tilage, and lead to disturbances in the structure of the subchondral spongy bone-substance. Through the formation of granulation-tissue proliferations which undergo caseous necrosis, larger defects may arise in the bone substance.

Syphilis can be transmitted to the foetus by the sperm as well as by the ovum. Paternal transmission is more common. After conception a transmission of syphilis from the mother to the foetus may take place. The transmission occurs most frequently in the second stage of syphilis. If infection and conception take place at the same time, the disease appears in the child in its most severe form; but even freshly infected parents may produce healthy children (*Neumann*). Syphilis transmitted by the mother during the early months of pregnancy kills the foetus. In the later months of pregnancy syphilis is as a rule not transferred to the child (*Neumann*).

Healthy women impregnated by syphilitic men may bear syphilitic children, but remain free themselves from syphilis throughout their lives. Women who are pregnant with a syphilitic foetus infected from the father, but who have themselves escaped contact-infection, acquire through such a pregnancy a certain, though very variable, degree of immunity (*Hochsinger*). The immunity of the mother is the result of the passage of immunizing substances to the mother from the foetus infected through the sperm, and is therefore not an absolute immunity (*Hochsinger*).

*Hügel* and *Holzhauser* affirm that syphilis can be transmitted to swine.

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§ 169. The *Bacillus lepræ* (described by Neisser in 1879 and 1881, and by Armauer Hansen in 1880) is a small slender bacillus, from 4 to 6  $\mu$  long. It is regarded as the **cause of leprosy**—also called *elephantiasis Græcorum*. It is found constantly and in great numbers in the diseased tissues (Figs. 486, 487, 488).

The foci of disease in leprosy are in general characterized by a proliferation (Fig. 486) which consists of cells of different sizes and of a fibrous ground tissue. The bacilli lie sometimes between (*e*), sometimes in the cells (*c*, *d*), and in the latter appear usually in such great numbers that the cells may become greatly swollen (*d*) and in part become changed into mono- and multinuclear giant-cells (Fig. 487). The latter occasionally enclose large vacuoles which contain great numbers of bacilli as well as the granular, thready detritus of the liquefied protoplasm. The nuclei remain preserved for a long time, and are pressed to the pe-

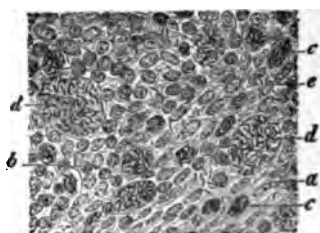


FIG. 486.

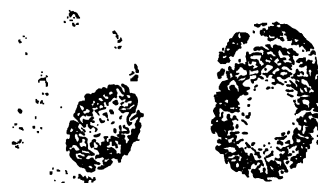


FIG. 487.

FIG. 486.—Tissue from a leprosy nodule (alcohol, fuchsin, methylene-blue). *a*, Fibrocellular tissue; *b*, round-cells; *c*, medium-sized cells; *d*, very large cells filled with bacilli; *e*, free bacilli.  $\times 200$ .

FIG. 487.—Giant-cells, with vacuoles containing bacilli, from leprosy proliferations of the nasal mucosa (alcohol, Gabbet's stain).  $\times 400$ .

riphery by the vacuoles containing the bacilli. Later they are destroyed, so that the entire cell becomes changed into a vacuole containing bacilli (Fig. 486, *d*). The cells in which the bacilli lie are in part the original cells of the tissue, and in part newly formed cells.

The bacilli are surrounded by a slimy envelope (Neisser), and react to stains in much the same manner as do tubercle-bacilli. The same staining methods may therefore be used for the former as for the latter. The stained bacilli often show clear spots or appear as if made up of stained granules.

According to Bordoni-Uffreduzzi the bacilli may be cultivated upon peptone-glycerin-blood-serum, upon gelatinized blood-serum, and upon boiled eggs. Upon these media they form threads of four times their original length, which are often swollen into a club shape at the ends. Czajlewski cultivated bacilli, showing a moderate acid-resisting power,



obtained from the nasal secretions of a leprosy individual, upon sheep's blood-serum with the addition of six per cent. glycerin. The pure cultures thus obtained were then cultivated upon various ordinary nutrient media. He regards this bacillus as identical with the one cultivated by Bordoni-Uffreduzzi from the bone-marrow of a case of leprosy. Finally Teich reports observations concerning the successful culture of lepra-bacilli. Babes, who also cultivated lepra-bacilli, regards them as closely related to the diphtheria-bacillus. Whether the bacilli form spores is still a disputed point.

Inoculations of animals have up to the present time not given positive results. It is said that in rabbits an increase of the bacilli and a tissue-proliferation may take place at the point of inoculation (Damsch, Vos-

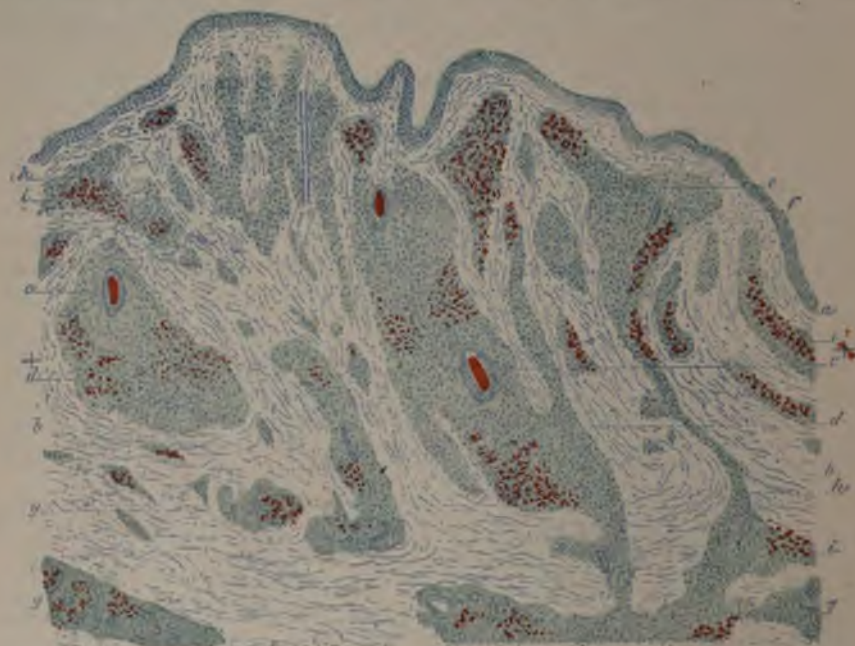


FIG. 488.—Section through a leprosy nodule of the skin (alcohol, Gabbet's method). *a*, Epidermis; *b*, corium; *c*, hair-follicle; *d*, leprosy focus in the neighborhood of the hair-follicle; *e*, duct of sweat-gland; *f*, leprosy nodule about duct of sweat-gland; *g*, leprosy foci in the neighborhood of sweat-gland; *h*, leprosy focus having no especial relation with any of the specific skin structures; *i*, foci of bacilli.  $\times 32$ .

sus), but no disease extending over a large area of the body can be produced. Schottelius and Bäumlér inoculated apes subcutaneously with freshly excised pieces of leprosy skin and with pieces of leprosy tissue rubbed to an emulsion in warm bouillon and warm blood-serum, but obtained negative results. According to Campana and Wesener the bacilli are taken up from the inoculated pieces by wandering cells, but give rise to no specific infection and do not multiply. Czaplewski was able to produce in rabbits, guinea-pigs, and mice by means of inoculations of cultures of the bacilli only slight and transitory inflammations.

The infection of man takes place by a direct or indirect transfer from individual to individual. The nasal secretion is especially infectious (Sticker), particularly when leprosy suppurations are present in the



nose. In the case of leprous affections of the respiratory tract the sputum may contain bacilli; and in the formation of nodules and ulcers in the skin the secretions from the latter may also contain the bacilli. Contagion seems to result most frequently from the nose (Sticker); in favor of this view speaks the fact that the anterior nasal region is usually involved very early. The bacilli are spread throughout the body chiefly by the lymphatic system; but they may also get into the blood-stream.

Besides the nose, the skin and the peripheral nerves are chiefly concerned in the disease; but the bacilli may multiply in other tissues, as



FIG. 489.—*Leontiasis leprosa*. (After G. Münch.)

in the testicles, liver, in the ganglia, and in the spleen, thereby giving rise to foci of disease in the organs.

At the place of colonization the bacilli excite inflammation with tissue-proliferation. Granulation tissue containing blood-vessels is formed; this remains for a long time in a condition which is characterized by great richness in cells, and forms the basis for nodules and tumors in the skin and nose and for spindle-shaped thickenings of the nerves, and is the cause of the irritation and later of the degeneration and destruction of the nerve-fibres. The bacilli and the tissue-proliferations caused by their multiplication often group themselves in the skin about the hair-follicles (Fig. 488, *d*), the ducts (*f*), and the coil (*g*) of the sweat-glands, but such a relationship is not always to be seen (*h*). Moreover, the bacilli may penetrate into the blood-vessels, the hair-follicles, and sweat-glands (Touton), and thence on to the surface of the skin. Infec-

tion of the arterial walls causes a proliferating arteritis, by which the walls become greatly thickened and the lumina narrowed. In the nervous system the bacilli are found both in the connective tissue and in the nervous elements, particularly in the ganglion cells (Sudakewitsch). The cells occupied by them undergo degeneration in the course of time, occasionally with hydropic swelling and the formation of vacuoles.

The tissue-proliferations caused by the growth of the bacilli may almost wholly disappear through the disintegration and absorption of the cells after the condition has lasted for years; but there always remain indurations rich in cells and pigmentations in the skin. Caseation never takes place.

*Leprosy of the skin* occurs especially in the face, on the extensor surface of the knees and elbows, as well as on the back of the hands and feet. It begins with the formation of red spots which either vanish, leaving pigmented spots behind, or become elevated into nodules of a brownish-red color (*lepra tuberosa sive tuberculosa sive nodosa*). In the region of the red spots the tissue contains large numbers of bacilli (Philipson), which for the most part lie within the vessels, and already at this stage the proliferation of the tissue can be demonstrated. According to the investigations of Müller the vesicular eruptions which occur in leprosy, and were formerly regarded as the sequelæ of the leprous disease of the nerves, are caused by the presence of the bacilli.

The nodules may remain unchanged for months, or they may increase in size and become confluent, so that very large protuberances may be formed, which, because of the distortion of the face thereby occasioned, have given occasion for the designation *facies leontina* (Fig. 489).

Through *external influences* ulcers may be produced which show no tendency to healing. New nodules appear occasionally following erysipelatos reddenings and swellings of the skin. The glands of the submaxillary and inguinal region swell to form very large nodules.

*Leprosy of the nerves* (*lepra nervorum sive anæsthetica*) leads first to hyperæsthesia and pain, later to anæsthesia, more rarely to motor paralysis in the region of the affected nerves. The further consequences of the disease of the nerves are disturbances which express themselves in the skin by the formation of white and brown spots (*lepra maculosa, morphea*



FIG. 490.—*Lepra anæsthetica ulcerosa* of the leg and foot. (After G. Münch.)

*nigra et alba*), and in the bones and muscles by atrophy. Since those suffering from the disease are likely to injure themselves after the appearance of anæsthesia, ulcers are often formed at a later period (Figs. 490, 491) which cause deep erosions and may lead to the loss of entire phalanges (*lepra mutilans*).

Leprosy of the skin and of the nerves are usually combined; more rarely do they occur alone. Besides the nose, skin, and nerves, the cen-



FIG. 491.—*Lepa anasthetica mutilans*. Partial destruction of the fingers; ulcers in the hand. (After G. Münch.)

tral nervous system, mucous membranes, cornea, the cartilages, liver, lungs, spleen, lymph-glands, and the testicles, become diseased.

In Europe leprosy is confined mainly to Norway, Sweden, Finland, the Baltic Sea provinces of Russia, and the coasts of the Mediterranean; but occurs sporadically in other regions. It occurs very frequently in Hindustan, China, Sumatra, Borneo, Java, and Mexico, on the northern and eastern coasts of South America, in Upper and Lower Guinea, in Cape Colony, and on the northern coast of Africa.

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§ 170. The **Bacillus mallei** is a bacillus discovered by Löffler, Schütz, and Israël in glanders foci; and later confirmed and studied by Weichselbaum, Kitt, and others. It is to be regarded as the **cause of glanders** (*malleus*, *malasimus*) and of *farcy* (*skin glanders*, *malleus farcinosus*), a contagious disease of horses, which occurs in man chiefly through transmission from horses.

The glanders bacilli are very small, slender rods, which occur in the diseased foci, sometimes scattered, sometimes lying together in small clumps. Alkaline methylene-blue or gentian-violet are employed especially for their staining.



The stained bacilli often show clear spots, which have been regarded by many observers as spores, but by Löffler as evidences of degeneration. The bacilli are present chiefly in the glanders-foci, but at times appear in the blood of the affected individual (Löffler, Kitt).

The bacilli grow at a temperature of  $30^{\circ}$ – $40^{\circ}$  C., upon coagulated blood-serum, as well as upon slices of boiled potato, and upon potato-pap. Upon the latter they form amber-yellow coatings that later become red. Upon blood-serum they form small yellowish transparent drops which later become milky white. Upon agar the colonies are grayish-white. In cultures club-shaped forms and threads are not infrequently seen. Spore-formation has not been demonstrated.

Horses, asses, sheep, young dogs, goats, cats, guinea-pigs, and field-mice are suitable for inoculation. In cats, after inoculation, there develop in the testicles cellular foci consisting essentially of leucocytes



FIG. 492.—Glanders of a cat's testicle (Müller's fluid, hæmatoxylin). *a*, Seminiferous tubules; *b*, *c*, tubules filled with leucocytes; *d*, foci of leucocytes in the connective tissue.  $\times 90$ .

(Fig. 492), which lie partly inside the canaliculi (*b*, *c*) and partly around them (*d*). The injection of the pus of glanders into the peritoneal cavity of male guinea-pigs causes the testicles to swell rapidly (Straus). After subcutaneous inoculations ulcers develop at the seat of inoculation, followed by swelling of the neighboring lymph-glands. Later, nodules may develop in the internal organs, and ulcers may be formed in the nose. Typical glanders may be produced in horses and asses. Cattle, white mice, and house-mice are immune.

The usual atrium of infection in horses is the mucous membrane of the nose; following this is the involvement of the submaxillary glands, and further a metastasis in various organs. In the nasal mucosa there arise as the result of the infection either diffuse cellular infiltrations of the mucosa or subepithelial nodules of the size of a millet-seed or a pea.

In chronic farcy of the skin larger nodules are developed which join together in rows, forming worm-like cords.

The nodules of the mucous membrane break down easily. The cells of which they are composed bear precisely the character of pus-corpuscles. Through the disintegration, softening, and suppuration of the nodules ulcers with yellowish infiltrated bases are formed. These enlarge through a progressive, nodular or more diffuse infiltration and subsequent disintegration of the edges of the ulcer, as well as through the confluence of neighboring ulcers. Horses dying of glanders often present in the mucosa of the nasal septum very extensive irregularly shaped, sinuate ulcers, with eroded edges and floors covered with gray and yellowish material. In addition to these there are numerous small, lenticular ulcerations and gray or yellowish nodular foci which are on the point of breaking down. The whole process is closely related to purulent inflammation. The healing of the ulcer is characterized by the formation of radiating scars.

The cervical lymph-glands are constantly swollen and inflamed. Of the internal organs the lungs especially are involved. They contain either nodules having a caseated and disintegrated centre and a grayish cellular periphery, or foci of lobular pneumonia, which present either a clear gray or a more hæmorrhagic appearance, or through fatty and cheesy metamorphosis become opaque and yellowish-white. Occasionally the mucosa of the alimentary tract contains nodules of varying size, in part clear gray and consisting of cellular tissue, in part opaque yellowish-white, undergoing caseation or approaching suppuration. The spleen, liver, kidneys, and bone-marrow may also contain nodules.

In farcy, which runs a more chronic course than glanders, there are formed in the skin and muscles nodules consisting of a small-celled tissue which later undergoes retrogressive metamorphoses, caseates and disintegrates.

In man an infection with glanders takes place usually through small wounds of the skin, but may also occur primarily in the mucous membranes adjacent to the skin. In the skin and subcutaneous tissue it gives rise to nodular, pustular exanthemata, carbuncular and phlegmonous inflammations which may result in suppuration, and to purulent inflammations of the lymph-vessels and lymph-glands. In the mucosa of the respiratory tract catarrhs are produced and suppurating nodules and nodes are formed, leaving ulcers behind. In the internal organs metastatic small-celled nodules are formed, showing a tendency to suppuration; also extensive abscesses and purulent infiltrations, especially in the muscles. In chronic farcy which may last for years, large nodules are occasionally formed in the skin and muscles which through disintegration give rise to ulcers which heal with difficulty. For the diagnosis of the condition the bacteriological examination and inoculation experiments are necessary.

According to the investigations of *Kalning*, *Preusse*, and others, an active poison, *mallein*, may be extracted from cultures of glanders bacilli which, when injected in small doses into horses sick of glanders, causes a febrile rise of temperature, and may be used as a diagnostic aid.

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§ 171. As the **Bacillus of rhinoscleroma**, Frisch, Pellizari, Chiari, Cornil, Alvarez, Köbner, Paltauf, von Eiselsberg, Dittrich, and others have described a bacillus with rounded ends, which is constantly present in the diseased condition known as *rhinoscleroma* or *scleroma respiratorium* (Bornhaupt, Wolkowitsch), and is therefore regarded as the cause of the same. It stains best with methyl-violet, the sections being left in the stain for twenty-four to forty-eight hours. After staining, the sections are treated with iodine water, or left in absolute alcohol for one to three days.

The bacilli for the chief part have a hyaline capsule. According to Paltauf, von Eiselsberg, Dittrich, Wolkowitsch, and others they may be cultivated upon blood-serum, gelatin, agar-agar, and potatoes, and also form capsules in the cultures. When grown in bouillon they show on the contrary no capsules (Dittrich). Stab-cultures in gelatin resemble closely the nail-cultures of the Friedländer pneumonia-bacillus, but are of a translucent grayish-white and not dead white. The bacilli stain

more easily than the pneumonia bacilli, and also stain by Gram's method. Stepanow observed, in inoculations into the eyes of guinea-pigs, progressive inflammations and proliferating granulations containing the bacilli and hyaline degenerated cells.

**Rhinoscleroma** occurs chiefly in eastern Austria and southwestern Russia; isolated cases have been observed also in Silesia, Italy, Egypt, Belgium, Sweden, Switzerland, and Central America. It is a chronic disease progressing for years, beginning in the nose (Wolkowitsch), more rarely in the pharynx, larynx, or palate, and extending thence to neighboring parts—the external nose, lips, lachrymal duct, trachea, etc. In the nose the disease is characterized by a thickening of the nasal wall which is sometimes diffuse, sometimes elevated or nodular. The external skin takes on a red or brownish-red color, becomes stiff and fissured and covered with scales. In the throat and respiratory tract dense, cartilage-like infiltrations are sometimes present, at other times a contracting cicatricial tissue is formed. The infiltrations may appear in the form of nodes and nodules or as elevations and flattened areas of thickening, or they may be spread out more diffusely. By the transformation of the infiltration into scar tissue marked deformities of the



FIG. 493.



FIG. 494.

FIG. 493.—Section of rhinoscleromatous tissue, with numerous degenerated and vacuolated cells containing bacilli (osmic acid, hæmatoxylin). Preparation by Stepanow.  $\times 340$ .

FIG. 494.—Cells in condition of hyaline degeneration, and hyaline spherules, from rhinoscleromatous tissue of the vocal cord and of the nose. Preparation by Stepanow. *a, b, c, d*, Hyaline-degenerated cells containing small bacilli; *e*, hyaline cells with encapsulated bacilli; *f, g*, cells with hyaline spherules; *h*, free hyaline spherules. *a, b, c, d*, Stained with Löffler's solution; *e*, with hæmatoxylin; *f, g, h*, with fuchsin.  $\times 425$ .

affected organs may be produced. Deep destruction of the tissues is absent; superficial ulcerations may, however, occur. On section the infiltrated tissue appears yellowish, spotted, but not infrequently shows a gray or grayish-red color. The tissue of the affected areas consists partly of granulation tissue, partly of fibrous connective tissue. If the former extends to the epithelial covering there appear in part proliferations, in part degenerative processes in the epithelial cells, the latter being characterized by the formation of vacuoles and by an infiltration of the part with round cells. According to Stepanow the vacuoles may contain bacilli.

The granulation tissue itself shows in many places no especial peculiarities; rather does it present the same conditions present in other inflammatory infiltrations and proliferations of connective tissue. In other places, on the contrary, there may be found a larger or smaller number of large connective-tissue cells containing one vacuole or showing a total vacuolar degeneration or a reticulated structure, in the meshes



of which bacilli may be demonstrated (Fig. 493), some of the latter possessing capsules. It cannot be doubted that the multiplication of the bacilli in the cells is the cause of the cell-degeneration.

Besides the cells showing vacuolar degeneration there also occur cells of various shapes which have undergone hyaline change (Fig. 494, *a, b, c, d, e*). These also contain bacilli with and without capsules, and also coccus-like forms. Through the loss of their nuclei these cells may become converted into non-nucleated homogeneous lumps (*d*). Finally, there also occur cells which enclose hyaline spherules (*f, g*), and free spherules are also found lying in the tissues (*h*). In places not yet affected by cicatricial retrogression the hyaline formations may be present in large numbers.

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§ 172. The *Actinomyces* or *ray-fungus* is a polymorphous fission-fungus which appears in different forms of growth in the human and animal organism as well as in cultures. It is the cause of *actinomycosis*, a disease occurring in man as well as in cattle, swine, and horses, and characterized by a progressive inflammation that produces in part granulation tissue and connective tissue, and in part pus. The botanical position of the fungus is still unsettled. By many it is classed with the *thread-fungi*, others group it with the *polymorphous bacteria*. Boström places it in the group *cladothrix*; Kruse, in the group *streptothrix*.

The masses of fungus formed in the tissues by the organism were long ago observed by Langenbeck and Lebert, but their significance was not rightly interpreted. The observations of Hahn, supplemented by those of Bollinger and Harz, first led to a correct interpretation of the ray-fungus occurring in domestic animals. Israël shortly after found a similar fungus in man; and Ponfick soon after gave his opinion in favor of the identity of actinomyces of cattle with the fungus discovered by Israël in man.

According to the investigations of Boström actinomyces differs from the bacilli in the fact that in cultures upon beef's-blood serum or agar it forms *branching threads*. The threads of the cultures are partly straight, partly wavy, at times also twisted spirally. They break up by transverse division



FIG. 495.

FIG. 495.—*Actinomyces hominis*. Teased preparation.  $\times 700$ .

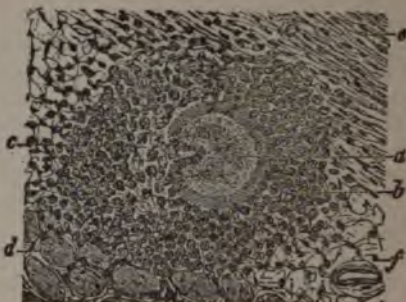


FIG. 496.

FIG. 496.—Actinomycosis of the tongue (alcohol, alum carmine.) *a*, Actinomyces druse; *b*, *c*, cellular nodules; *d*, transverse section of muscle; *e*, *f*, connective tissue with blood-vessels.  $\times 175$ .

into short rods and coccus-like forms, which under suitable conditions again grow into threads.

Within the human and animal organism the fungus appears in masses in the form of little granules scarcely recognizable by the naked eye, or

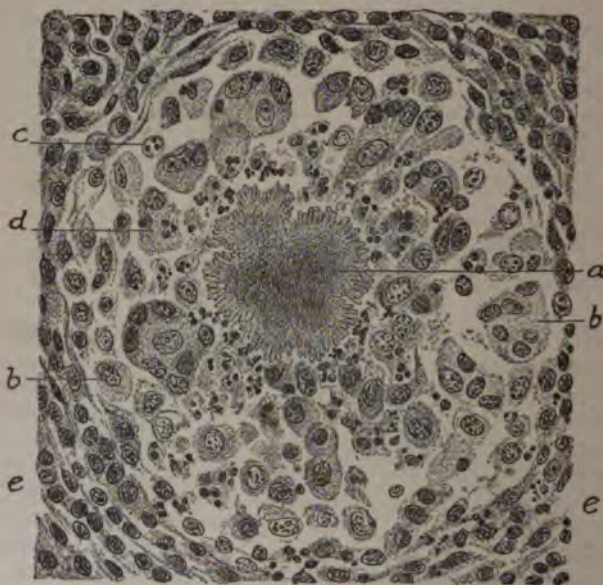


FIG. 497.—Actinomyces druse, surrounded by giant-cells and pus-corpuscles (alcohol, hæmatoxylin, eosin). *a*, Fungus druse; *b*, mononuclear and multinuclear fibroblasts; *c*, pus-corpuscles; *d*, fibroblasts, enclosing a pus-corpuscle; *e*, granulation tissue.  $\times 500$ .

in spherules up to 2 mm. in diameter. These are sometimes colorless and transparent, at other times white and opaque, sometimes yellow, or brown, or green and yellowish-green. Many of the smaller ones consist

only of a feltwork of fine, partly branched threads, some of which are straight, or wavy, or twisted.

The majority of the granules contain, moreover, peculiar club-shaped structures (Fig. 495), which form the ends of the threads, and if present in large numbers, as is the case particularly in the larger granules, have a radial arrangement (Figs. 496, *a*, 497, *a*), and so give to the colony of the fungus a ray-like appearance. Occasionally hand- or fan-like forms develop on the ends of the threads. According to Boström all these peculiar structures are due to a swelling of the membrane of the threads,

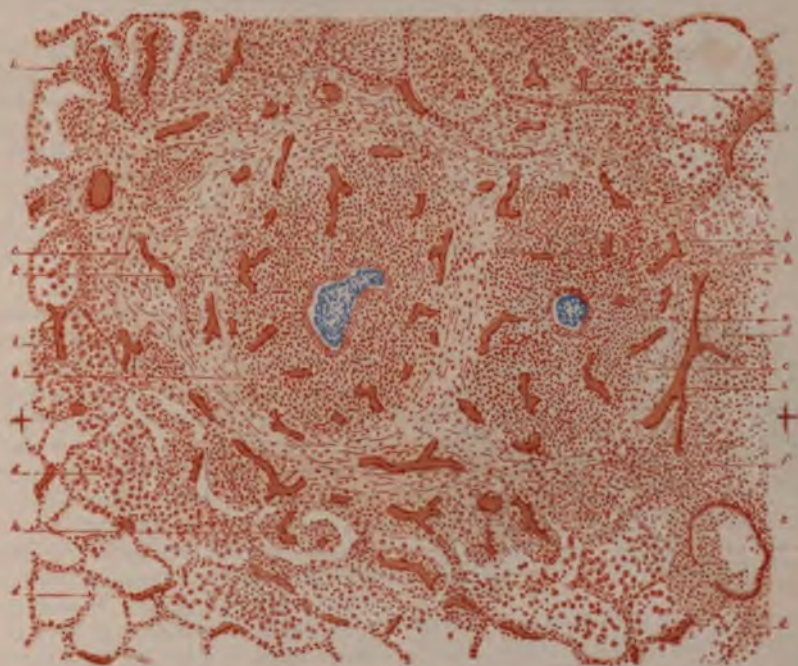


FIG. 498.—Actinomycosis of the lung (alcohol, carmine, Gram's). *a*, Fungus druse; *b*, small-celled nodule; *c*, fibrous tissue; *d*, alveoli filled with large and small cells; *e*, bronchiole with wall infiltrated with cells; *f*, small-celled focus in the neighborhood of the bronchus (*e*); *g*, alveoli filled with vascularized connective tissue; *h*, connective tissue growing into the alveoli; *i*, blood-vessels of the lung tissue; *k*, blood-vessels of the inflamed area.  $\times 42$ .

and are to be regarded as retrogressive changes resulting from an exhaustion of the food-supply.

The actinomycetes is usually taken into the body with the food or the respired air, and finds its first development often in the mouth. Since the threads and granules of actinomycetes in many respects correspond closely to the form of fungus known as *leptothrix*, which is frequently found in the mouth cavity, the latter also forming club-like swellings on the ends of the threads (Israel), it is difficult to determine the presence of actinomycetes in the mouth, in which situation, moreover, it appears not to form the characteristic granules. The fungus has not yet been demonstrated outside of the animal organism. It must be remarked that very often bits of higher plants (beard of wheat, splinter of wood) have



been found in the pus of actinomycotic foci, and that the swallowing of portions of plants (spike of grain [Bertha]), or the contamination of wounds with vegetable material, have in certain cases preceded the development of actinomycosis. It is, therefore, very probable that the fungus is present upon the higher plants or upon wood.

If the ray-fungus succeeds in settling in a tissue it excites an inflammation in its neighborhood. While the fungus which has penetrated into the tissue develops a mycelium and a fungus-granule (Figs. 496, *a*, 497, *a*, 498, *a*) there is formed in its neighborhood a nodular focus of inflammation, which at first consists of small round cells (Figs. 496, *b*, *c*; 498, *b*); but later, in addition to pus-corpuscles (Fig. 497, *c*), also contains epithelioid cells and giant-cells (*b*, *d*).

The fungus-granules may increase within the nodule and lead to its enlargement; and it very often happens that cellular nodules the size of a pea and larger contain a large number of fungus-foci, which are usually situated in the periphery of the same. At the same time new fungus-foci, and consequently new cellular foci, may appear in the neighborhood. The further spread of the infection takes place by means of small rods

and threads, which are broken off from the larger masses, and may be seen in the tissues partly free and partly enclosed in cells.

Larger nodules often undergo in time a purulent liquefaction of their central portions, leading to the formation of small *abscesses*, which may become confluent to form larger *pus-cavities* or *sinuses*. In the neighborhood of the cellular areas (Fig. 498) there develops early an active *proliferation of tissue*, which leads to the *formation of vessels* (*k*) and young *granulation tissue*, which later becomes transformed into *connective tissue* (*c*, *g*, *h*). If the connective-tissue proliferation attains very considerable proportions, it leads to an *induration* (Fig.



FIG. 499.—Frontal section through the nose and upper jaw of a steer affected with a tumor-like actinomycosis. *a*, Nodules consisting of connective tissue, bone, and small pus foci. One-fourth natural size.

498), often also to an *enlargement of the tissue*. The connective-tissue proliferation may finally extend into the small-celled areas, and replace the latter, the fungi probably being destroyed in this way.

If the connective-tissue proliferation becomes predominant there arises in the course of weeks and months a nodular formation of tissue (Fig. 499, *a*) which in cattle may attain the size of a man's fist or even reach a much greater size. The tumor consists partly of dense connective tissue, partly of granulation tissue, and partly of intermediate stages between the two. It always contains small cellular foci or even cavities due to disintegration, in the purulent contents of which the fungus-masses are found in the form of the granules described above. When the fungus develops within the jaw-bone there occurs at the same time an active new-formation of bone at the periphery (Fig. 499, *a*) of the process.

A predominance of tissue-necrosis and of suppuration over tissue-production gives rise to more or less extensive *sinuous cavities* and



branching fistulous tracts communicating with one another. The walls of these consist of granulation-tissue and hyperplastic connective tissue, and here and there contain fungus-foci. The masses of fungi may in part become calcified.

In cattle the disease affects chiefly the lower jaw, but may involve also the upper jaw (Fig. 499, *a*), the tongue, throat, larynx, œsophagus, stomach, intestinal wall, skin, lungs, and subcutaneous and intermuscular tissues. In these regions it leads to the formation of more or less extensive nodular tumors of the character described above, and was formerly given various names, such as osteosarcoma, bone-cancer, bone-tuberculosis, lumpy jaw, wooden tongue, tuberculosis of the tongue, lymphoma, fibroma, worm-nodules, etc. In *man* the infection, so far as is known, takes place through the mouth, fauces, œsophagus, stomach, intestine, and lung, or through some external injury. In the first-named region an infection of actinomyces may take its start from carious teeth (cavities or fistulæ), or from any injury to the soft parts of the jaw or cheek. Thence it spreads over the neighborhood and may finally involve the face and the hairy portions of the head, as well as the throat, neck, back, and breast.

With the advent of the process there arise swellings which later soften and give fluctuation. When the latter is the case, pus is formed which is at times thin and watery, at other times more viscid, and contains the characteristic granules. If these abscesses break externally there may be formed fistulous tracts, which may either close again, or continue to secrete pus.

Besides these purulent foci, which sometimes are small, at other times extensive, there is constantly formed more or less granulation tissue, which at times may be very abundant. As a result of fatty degeneration and disintegration of its elements the granulation tissue often becomes partially whitish or yellowish or reddish-white in color, and permeates the diseased tissue in an irregular manner. In other places it comes to a development of connective tissue, particularly in those places where the process is not spreading.

Through this development of connective tissue a local healing resulting in cicatricial indurations may take place, but in other parts the process usually makes further progress and may under certain circumstances lead to very extensive destruction. If the disease encroaches upon the bones of the spinal column or of the thorax these may be gradually destroyed from the surface, and become rough, eroded, and carious. In rare cases the jaw-bone may be attacked from within through an alveolar process, and so undergo destruction. From the base of the skull the process may extend into the interior of the skull and lead to actinomycotic meningitis and encephalitis.

In primary infection of the respiratory apparatus the process takes the form of a bronchopneumonia characterized by the formation of nodular foci (Fig. 498, *b*) the central portions of which at an early stage assume a yellowish-white color. Through the disintegration of the inflammatory foci cavities may be formed which contain fluid, pus-corpuses, fatty detritus, spherules of fatty granules, disintegrated red cells, and masses of actinomyces. The tissue lying between the mycotic foci suffers a more or less extensive, often very marked, inflammatory thickening and induration (Fig. 498, *c*), and through a new-formation of connective tissue may be transformed into a callous, slate-gray or gray and white mass, devoid of air, and later undergoing cicatricial contraction.

In this manner a large portion of the lung may become converted into a mass of connective tissue.

From the lung the process sooner or later extends to the visceral pleura, and from this to the costal pleura or to the pericardium, giving rise in these places to inflammatory exudations and proliferations of tissue, which may lead to adhesions between the opposite layers of the pleura or pericardium. From the costal pleura the cellular infiltration as well as the pus formation and the fatty degeneration and disintegration of the granulation tissue may extend between the ribs to the outside, and spread in the contiguous soft parts, in the connective tissue and muscles, and may finally break through in places. From the lungs a rupture may sometimes take place into the mediastinum or pericardial sac, and finally into the heart. Under certain conditions a rupture may occur through the diaphragm into the abdominal cavity, or the process may extend from the posterior mediastinum into the retroperitoneal connective tissue.

The secondary areas of destruction lying outside of the lung often reach an extremely large size, while in the lung the primary process advances but little and undergoes cicatrization. At one time the purulent softening predominates, at another time the formation of granulation tissue and the induration.

Primary actinomycosis of the intestinal tract begins with the formation of plaque-shaped whitish patches of the fungus (Chiari) or of nodular mucosal and submucosal foci (Zemann), which contain the specific fungus, and lead to ulceration through the occurrence of disintegration. From the intestine the process spreads over the peritoneum and the retroperitoneal connective tissue, as well as to the organs adjacent to the primary focus—for example, the liver; and may finally break through the abdominal wall. At the places where the fungi develops the proliferating foci of inflammation described above are produced. If faecal masses gain access to the tissues in case of intestinal rupture, gangrenous abscesses will arise.

*Metastasis* may be associated with the local progression of the disease, but is rather rare. It usually results from a direct rupture into a blood-vessel. The metastases arising from a primary focus in the intestine are found especially in the liver; those arising from a primary focus in the lungs are found in the skin, muscles, bones, brain, intestine, and kidneys. The metastatic nodules behave like the primary foci. In rare cases there occur also primary foci of actinomycosis in the internal organs—for example, in the brain and liver. The portal of entrance in these cases may not be demonstrable.

Johne, Ponfick, Boström, Wolff, and Israël have attempted inoculation experiments upon animals, and according to their reports have obtained positive results in part (Johne, Ponfick, Wolff, and Israël). Wolff and Israël, by the inoculation of rabbits and guinea-pigs, obtained in almost all cases a characteristic disease with the formation of inflammatory foci containing the fungus-masses. They were also able to again cultivate upon agar-agar the fungus contained within these foci.

*Lery*, as well as *Kruse*, assumes that there are two forms of actinomyces, an aerobic cultivated by *Boström*, and an aerobic cultivated by *Wolff*, *Israël*, *Aschoff*, and himself, the two forms being closely related. An attempt by *Lery* to change one form into the other was not successful, although the aerobic form could be made to grow under anaerobic conditions. He regards the *actinomyces* as well as the fine-threaded fungus known as *streptothrix* as belonging to a group, the *Hyphomycetes*, characterized by the

formation of branching, probably unicellular mycelia and which multiplies through an acrogenic snaring-off of conidia-chains or through fragments of threads resembling bacilli. Since the ray-fungi do not correspond to any one of the known hyphomycetes-groups, he places them in a separate group, the *Actinomycetes*. In this group he also places the tubercle-bacillus, the lepra-bacillus, the diphtheria-bacillus, and the bacillus of glanders. *Lubarsch* regards the streptothrices, with which he classes the ray-fungi (to which the tubercle-bacillus also belongs), as a transition form between the bacilli and the moulds.

*Berestnew* also distinguishes different forms of actinomycetes (cultivated by him from straw, hay, etc.), and, in addition to *actinomycosis*, recognizes a condition of *pseudo-actinomycosis*, which runs a similar course to that of the former, but is caused by fungi which do not belong to the ray-fungi. *Kruse* likewise regards the etiological factor of an actinomycosis as being of varied nature and not representing a definite entity. *Schürmayer* emphasizes the variability of actinomycetes according to the conditions of growth.

*Gazzolino* found in the pus of a skin affection resembling actinomycosis granules and bacilli, from which a spore-producing bacillus (*Bacillus filamentosus*) was cultivated, which produced no branching threads.

Recently *Eppinger* ("Ueber eine neue pathogene Cladothrix und eine durch sie hervorgerufene Pseudotuberculosis," *Beit. z. path. Anat. v. Ziegler*, ix., 1891) found, in the pus of an old brain-abscess causing death through meningitis, a polymorphous fission-fungus, which he designated as *Cladothrix asteroides*. Its characteristics were determined by cultivation and by inoculation into animals. Since the changes occurring in the lungs and bronchial glands of the affected individuals resembled those of tuberculosis, and as a disease suggesting tuberculosis resulted from the inoculation of this fungus into guinea-pigs and rabbits, the disease caused by the fungus may be designated *pseudotuberculosis cladothrichica*.

*Buchholz* ("Ueber menschenpathogene Streptothrix," *Zeits. f. Hyg.*, xxiv., 1897) found in a pneumonic lung containing a large disintegration cavity with ragged walls, that the diseased lung-tissue was infiltrated with fine, branching, and many times broken threads, which stained with Gram's method. He regarded the fungus, which he was not able to cultivate, as a pathogenic streptothrix.

According to *Dunker* (*Zeitschr. f. Mikroskopie und Fleischschau*, iii., 1884) and *Hertwig* (*Arch. f. wissenschaft. u. prakt. Thierheilk.*, xii., 1886) there occurs in hogs a ray-fungus which is always situated in the muscles, particularly in the diaphragm, abdominal and intercostal muscles, and causes a degeneration of the muscle fibres in its neighborhood and proliferation of the intermuscular connective tissue. The fungus-masses form radially arranged clubs. They readily undergo calcification and then form white points in the flesh.

According to investigations by *Kanthack* ("Madura Disease and Actinomycetes," *Jour. of Path.*, 1892), *Boyce* ("Upon the Existence of More than One Fungus in Madura Disease," *Trans. Phil. Soc.*, vol. clxxxv., 1894; *Hyg. Rundschau*, 1894), and *Vincent* ("Et. sur le parasite de pied de madura," *Ann. de l'Inst. Pasteur*, 1894), it is very probable that the disease occurring in India, known as *madura-foot* or *mycetoma*, is due to a polymorphous fission-fungus closely related to actinomycetes, and called by *Vincent* the *Streptothrix madura*. The disease consists in a gradual swelling of one extremity due to the formation of nodular deposits, which through softening become changed into abscesses and fistulous tracts, that upon pressure discharge peculiar brown or black, fish-roe, or truffle-like granules. *Kanthack* regards the fungus which is contained in the granules as identical with actinomycetes; but the investigations of *Vincent* and *Boyce* do not support this view. According to *Boyce* the streptothrix *madura* occurs in two varieties, one white with fine dichotomously branching threads, the other black with branching pigmented threads. *Unna* and *Delbanco* ("Anatomie des indischen Madurafusses," *Monh. f. prakt. Derm.*, 1900) also distinguish different forms of ray-fungi. The parasite of the madura disease has been known since 1874 (*Carter*, "Mycetoma or the Fungous Disease of India," London, 1874; *Lewis* and *Cunningham*, "The Fungous Disease of India," Calcutta, 1875; *Hirsch*, *Virchow's und Hirsch's Jahrbuch*, 1875, 1876), and was formerly known as *Chionophye Carteri*.

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§ 173. In addition to those already described there is a large number of **bacilli pathogenic for animals** which may also cause infection in man. The most important animal diseases caused by bacilli are symptomatic anthrax, swine-erysipelas, swine-plague, cattle-plague, and chicken-cholera.

The **bacillus of blackleg** or **symptomatic anthrax** (*Bacterie du charbon symptomatique*) is a rod with rounded ends about 3-5  $\mu$  long and 0.5-0.6  $\mu$  broad, and sometimes possessing independent motion. According to the investigations of *Bollinger*, *Feser*, *Arloing*, *Cornevin*, *Thomas*, and others it is constantly found in blackleg.

Blackleg occurs particularly in young cattle and in lambs, and is usually fatal within two days. It is characterized anatomically by a tumor-like swelling of the skin due to the exudation of a bloody serous fluid attended by the formation of gas in the subcutaneous, intermuscular, and muscular connective tissue. The bacilli are found in the region of the exudation and gas-formation, as well as in the spleen and liver. They do not stain with Gram's method.

According to *Arloing*, *Cornevin*, and *Thomas*, the bacilli may be cultivated, in the absence of oxygen, in chicken-bouillon, to which a small amount of glycerin and sulphate of iron is added. *Kitasato* and *Kitt* cultivated them in guinea-pig bouillon, agar, and gelatin in the absence of oxygen. They grow best at from 36°-38° C., and form spores in the middle or at the ends of the rods, whereby the latter become somewhat swollen. The addition of sugar and glycerin to the nutrient medium aids the growth.



The inoculation of cattle and sheep with bacilli which are attenuated by heating produces an immunity against virulent bacilli. Cattle, sheep, goats, rabbits; guinea-pigs, swine, dogs, cats, and chickens are susceptible to the bacilli of symptomatic anthrax; black rats are immune; horses and donkeys occupy an intermediate position.

The inoculation of guinea-pigs with virulent material—for example, with the dried juice of the muscle of cattle dying of blackleg—leads very quickly to a rapidly spreading swelling at the point of inoculation, due to the infiltration of the tissues with a bloody cedema. The bacilli spread with remarkable rapidity in the tissues, particularly in the subcutaneous and intermuscular tissue, and penetrate also into the muscles. They cause severe lesions of the vessels, leading to hæmorrhages and serous exudations, and after a time to an abundant emigration of leucocytes. The animals usually die on the second or third day after the swelling has spread over a portion of the body. The blood usually remains free from bacilli. Spores are not formed in the living body.

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The **bacillus of swine-erysipelas** (*Löffler*, *Lydtin*, *Schottelius*, and *Schütz*) is a bacillus from 0.6-1.8  $\mu$  long. It may be cultivated in bouillon, meat-infusion-peptone-gelatin, blood-serum, and sour milk.

In gelatin-plates it forms peculiar radiating and branched figures. In stab-cultures it grows out in white streaks from the stab-canal like the bristles of a test-tube brush. In cultures the bacilli may form pseudothreads. They sometimes enclose shining spherules which are regarded as spores. By means of pure cultures the disease may be reproduced in susceptible swine. House-mice and pigeons die within two to four days after inoculation, and their blood contains numerous bacilli.

In rabbits, inoculation is followed by an erysipelas-like inflammation which terminates either in a fatal general infection or in healing. Guinea-pigs and chickens are immune.

According to investigations by *Pasteur* and *Thuillier*, and confirmed by *Schottelius* and *Schütz*, the virulence of the bacilli for swine may be attenuated by progressive inoculations in rabbits. Susceptible swine inoculated with this vaccine do not die after inoculation and become immune to fully virulent bacilli.

Swine-erysipelas occurs particularly in young herds of highly-bred (English) hogs, while the common breeds are nearly or wholly immune. The disease is characterized by fever and the appearance of red spots, later becoming brown, upon the neck, chest, and belly. Intestinal hæmorrhages occasionally occur. More than half of the infected animals die, usually within a few hours or within four days. The autopsy shows swelling and localized hæmorrhages in the mucosa of the intestine, swelling and ulceration of the follicles, particularly in the ileocæcal region, swelling of the mesenteric lymph-glands, and petechiæ of the serous membranes.

The bacilli are found in the blood as well as in the lymph-glands, muscles, spleen, and kidneys, where they also lie in the blood-vessels. The majority are free; some are enclosed in leucocytes. They are stained by Gram's method.

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The **bacillus of swine-plague** is a small bacillus with rounded ends, 1-1.5  $\mu$  long, staining chiefly at its ends. It resembles the bacillus of chicken-cholera, and may be cultivated upon various media. It is regarded as the cause of the disease known in

Germany as "*Schweineseuche*" or *Schweinepest*, in England as *hog-cholera* or *swine-fever*, in America as *swine-plague* and *hog-cholera*, and in Sweden and Denmark as *swine-plague*; but it is not yet definitely determined whether the swine-diseases of different lands (with the exception of swine-erysipelas) are identical (see Preisz and Karlinski).

The anatomical changes in swine-plague vary with the localization of the infection. In the lungs there are found multiple areas of necrotic and hæmorrhagic pneumonia, and pleuritis. Intestinal infection leads to hæmorrhagic and diphtheritic enteritis and (in chronic cases) to caseous inflammations, which are accompanied by corresponding changes in the mesenteric glands, and occasionally also by peritonitis. The bacilli, besides being found in the infected areas, are present in large numbers in the blood in acute cases. Hogs, guinea-pigs, rabbits, and mice are susceptible to inoculations.

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The **bacillus of chicken-cholera**, or *avian typhoid*, a disease occurring epidemically among chickens, is a small bacillus from 1-1.2  $\mu$  long, often somewhat constricted in its middle. It was first studied by *Perroncito*, then by *Toussaint*, *Pasteur*, *Rivolta*, *Marchiafava*, *Celli*, and *Kitt*. The disease is characterized clinically by great exhaustion and stupor, occasionally also by diarrhoeal intestinal discharges; anatomically by swellings of the liver and spleen, hæmorrhages and inflammations of the intestine, and also frequently by pleuritis and pericarditis.

The bacilli are found in the blood and therefore also in the capillaries of the different tissues. They may be cultivated upon nutrient gelatin, blood-serum, and neutralized bouillon, as well as upon potatoes. They form white colonies. Feeding or inoculation of the bacilli causes in chickens a typical chicken-cholera; pigeons, sparrows, pheasants, rabbits, and mice are also susceptible to the bacilli. In sheep, horses, and guinea-pigs they produce abscesses at the point of inoculation.

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According to the view of *Voges* ("Krit. Studien u. exper. Untersuch. über die Bakt. d. hämorrhag. Septikämie und die durch sie bewirkten Krankheitsformen," Zeitschr. f. Hyg., xxiii., 1896, xxviii., 1898) the German *swine-plague*, *rabbit-septicæmia*, "*Wildseuche*," "*Buffelseuche*," *chicken- and duck-cholera*, *American hog-cholera*, *swine-fever* and "*Frettchenseuche*," are all caused by the same disease-agent—the **bacterium of hæmorrhagic septicæmia**—and represent one and the same disease, to which he and *Hueppe* give the name of *hæmorrhagic septicæmia*. *Preis* ("Schweinepest und Schweineseptikämie," Zeitschr. f. Thiermed., ii., Jena, 1898) distinguishes between *Schweinepest* and *Schweineseptikämie* as two different diseases caused by different bacilli. *Septicæmia* may be associated with swine-plague as a secondary infection. Swine-plague is characterized by caseous plaques and ulcerations in the intestine, enlarged and in part necrotic lymph-glands of the abdominal and inguinal regions, and necrotic infiltrations of the skin and kidneys; septicæmia, on the other hand, according to *Preis*, by a hæmorrhagic pneumonia, hæmorrhagic fibrinous pleuritis and pericarditis, and hæmorrhages from the kidneys. *Karlinski* ("Schweinepest und Schweineseuche," Zeit. f. Hyg., xxviii., 1898)

expresses himself in a similar manner and also distinguishes between *Schweinepest* and *Schweineseuche*.

The *Bacillus diphtheriæ columbarum* is a small, slender bacillus, which was isolated by Löffler ("Mittheil. a. d. k. Ges.-Amte," ii.) from the exudate of a pigeon dying of diphtheria, and is regarded (*Babes* and *Puscarin*, "Unters. über die Diphtherie der Tauben," *Zeitschr. f. Hyg.*, viii., 1890) as the probable cause of pigeon-diphtheria, a disease resembling human diphtheria. Löffler was able to reproduce the disease in pigeons but not in chickens by means of inoculations of pure cultures of the bacilli. Mice died in about five days after inoculation, and the bacilli were found in the blood-vessels of all the organs.

According to Löffler (l. c.) a bacillus is also present in the diphtheria of calves, but he was not able to cultivate it pure or to determine its pathogenic significance.

The diphtheria of calves and chickens is etiologically different from human diphtheria (*Escher*, "Ist die Diphtherie des Menschen auf Kälber übertragbar," *Fortschr. d. Med.*, vi., p. 324; Löffler, "Mittheil. a. d. k. Ges.-Amte," 1884; Pütz, *Fortschritte d. Med.*, v., p. 187).

Besides the above, there are many other bacilli which have been described as the cause of disease in animals. Thus, for example, according to Höflich ("Die Pyelonephritis bacillosa des Rindes," *Monatsh. f. prakt. Thierheilk.*, ref. *Centralb. f. Bakt.*, x.) and Enderlen ("Primäre infectiöse Pyelonephritis beim Rinde," *Deutsch. Zeitschr. f. Thiermed.*, xvii., 1891, ref. *Cent. f. Bakt.*, x.), the frequently occurring pyelonephritis of cattle is caused by a bacillus. Likewise, according to Nocard ("Note sur la maladie des bœufs de la Guadeloupe connue sous le nom de Farcin," *Ann. de l'Inst. Past.*, ii., 1888) the worm disease of the ox, which was formerly of frequent occurrence in France; and according to Oreste and Armanni ("Studi e ricerche intorno al barbone dei bufali," ref. *Cent. f. Bakt.*, ii., 1887) and von Ratz ("Die Barbonekrankheit," *Deutsch. Zeitschr. f. Thiermed.*, xxii., 1896), the plague occurring among the Italian buffalo known as *barbone dei bufali* is due to a bacillus (by Voges regarded as the bacillus of hæmorrhagic septicæmia). According to Nocard and Roux ("Le microbe de la peripneumonie," *Ann. de l'Inst. Past.*, 1898) the lung-plague of cattle is caused by an extremely small, motile bacillus, whose form is with difficulty determined. According to Bang ("Aetiologie des seuchenhaften Verwerfens," *Zeitschr. f. Thiermed.*, i., 1887) bacilli should be regarded as the cause of the epidemic abortion of cows. Siegel and Busenius ("Krankheitserreger der Mund und Klauenseuche," *Deutsch. med. Woch.*, 1897) have described a bacillus as the cause of foot-and-mouth disease; but according to C. Fränkel ("Der Siegelsche Bacillus," *Hygien. Rundschau*, vii., 1897) its pathological significance remains to be proved. Whether the microorganism described by Babes and Proca ("Aetiologie der Maul und Klauenseuche," *Centralb. f. Bakt.*, xxi., 1897) is the cause of foot-and-mouth disease is likewise still to be determined. Löffler and Frosch (*Obl. f. Bakt.*, xxiii., 1898, p. 871) are of the opinion that the nature of the infecting agent in foot-and-mouth disease has not yet been determined. Lundgren ("Die Rennthierpest," *Zeitschr. f. Thiermed.*, ii., 1898) found a bacillus similar to the bacillus of symptomatic anthrax, and pathogenic for mice and guinea-pigs, in an epidemic disease affecting the reindeer herds of the Laplanders in northern Sweden.

### 3. THE SPIRILLA AND THE DISEASES CAUSED BY THEM.

#### (a) General Remarks upon the Spirilla.

§ 174. The Spirilla, or Spirillaceæ, or Spirobacteria are divided into two genera, one of them called *Spirillum*, the other *Spirochæte*. Many writers recognize still another genus, *Vibrio*.

The genus *Spirillum* is characterized by the formation of short, stiff, shallow spirals, which in part possess flagella and show an active swarming movement. The wavy rods are also called *vibriones* by many writers.

*Spirillum* sive *Vibrio rugula* (Fig. 500, b) forms rods, from 6–16  $\mu$  long and 0.5–2.5  $\mu$  broad, simply bent or having a shallow turn, and moves by means of flagella. It occurs in swamp-water, fæces, and in the slime from the teeth.

*Spirillum* sive *Vibrio serpens* forms thin threads from 11–28  $\mu$  long, having three to four wavy turns, and is found in stagnating fluids.

*Spirillum tenue* has very thin threads about  $3-15\mu$  long, having 2-5 screw-like turns.

*Spirillum undula* (Fig. 500, a) consists of a thread from  $1-1.5\mu$  broad and  $8-12\mu$  long, having from one and a half to three turns, and furnished with a flagellum at one end. It occurs in various decomposing fluids and executes rapid twisting and darting movements.

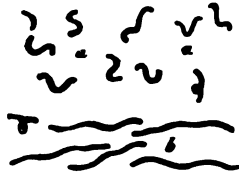


FIG. 500.—*Spirillum* or *Vibrio rugula* (b) and *Spirillum undula* (a), obtained from a cold infusion of finely chopped earth-worms. Dried preparation treated with gentian-violet.  $\times 600$ .

*Spirillum volutans* possesses threads  $1.5-2\mu$  thick and  $25-30\mu$  long, with two and a half to three and a half turns, and bearing a flagellum at each end.

The genus *Spirochæte* (Fig. 504) is characterized by long, flexible, closely-turned spirals.

The *Spirochæte plicatilis* forms long, very fine, closely wound threads, from  $100-225\mu$  long; it is of frequent occurrence in swamp-water and in gutters, and makes very rapid movements.

*Spirochæte buccalis* sive *denticola* is  $10-20\mu$  long, pointed at both ends, and is not infrequently observed in the secretions of the mouth and nose (cf. Fig. 187). It appears to possess no pathogenic significance.

The spirilla, so far as they are not pathogenic, have been but little studied. They are present in large numbers in the contents of privy-vaults. According to Prazmowski *Spirillum rugula* causes decomposition of cellulose, and forms terminal spores. According to Weibel a vibrio present in nasal slime presents many forms of growth. Esmarch succeeded in cultivating a spirillum, called by him *Spirillum rubrum*, upon the various ordinary media. In bouillon it forms spirals of from forty-three to fifty turns. Short spirilla execute lively movements, but long ones, on the contrary, slow movements or are motionless. The colonies in firm nutrient media are at the beginning pale, but in time the portions not exposed to the air take on a wine-red color. In the spirilla of old cultures there appear three to four clear, dull-glistening spots that do not stain, and are probably to be regarded as spores. Cultures which contain such spirilla are more resistant to drying than others, but they are, however, very easily killed by heat.

The long spirals may break up into short segments which possess only about three-quarters of a turn, but these may again grow in length, and undergo division.

Kitasato and Kutscher have also succeeded in cultivating spirilla.

### Literature.

#### (Life-history of the Spirilla.)

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**Kutscher:** Vibrionen u. Spirillenflora d. Düngerjauche. Zeitschr. f. Hyg., xx., 1895; Spirillum Undula minus u. majus. Cbl. f. Bakt., xviii., 1895.

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#### (b) The Pathogenic Spirilla.

§ 175. The *Spirillum cholerae asiaticæ*, or the *Vibrio cholerae*, also called *comma-bacillus* (*bacille-virgule cholérigène*), was discovered by R.



Koch in 1884, and is regarded as the cause of Asiatic cholera. The spirilla (Fig. 501) form small, comma-like, curved rods from 0.8–2  $\mu$  long.

Cultures of cholera-spirilla may be obtained upon a great variety of culture-media of a slightly alkaline reaction. The temperatures most favorable for their development lie between 25° and 30° C.; at between 16° and 8° C. they are still capable of a feeble development.

On gelatin-plates they form round, flat, yellowish discs which liquefy the gelatin only slowly. At a low magnification the cultures are irregular in outline, and of a granular or furrowed and rough surface, appearing as if strewn with small particles of glass (Koch). Through the liquefaction of the gelatin in its immediate neighborhood there is formed a funnel-shaped cavity, to the bottom of which the colony sinks.

Stab-cultures in gelatin form on the second day a whitish cord corresponding to the line of the stab (Fig. 502), in the immediate neighborhood of which the gelatin is liquefied. The canal thus formed widens out above into a funnel part which is filled in its lower portion with liquefied gelatin and in its upper with air. The widening of the funnel of the canal of inoculation takes place very slowly, so that its edge reaches the wall of the tube only after five to six days.

On potatoes at from 30°–35° C. the spirilla form light-brown cultures, on agar-agar grayish-yellow slimy cultures. They grow also in bouillon, blood-serum, and milk.

They do not increase in pure water (Bolton), but do so in water contaminated with substances furnishing nutrient material.

The cholera-spirilla are aërobic, but they are also able to grow under anaërobic conditions. According to investigations by Hueppe cultivation with a deficient supply of oxygen increases the virulence of the culture; but the resisting power against injurious agents—for example, against acids—is on the other hand lowered; with free access of oxygen the reverse takes place. Pfeiffer, however, found that young cultures grown in the presence of oxygen also contained poison. The spirilla present in fresh dejections (Hueppe) are easily killed, and have but little infecting power; whereas the growth of the spirilla outside of the body increases their resistance (for example, against the gastric juice) and makes them at the same time more capable of causing infection in new individuals. They are easily destroyed by desiccation in free air (Guyon) and by high temperatures, and by boiling for a short time. They are easily supplanted by saprophytic bacteria when the nutrient material and the temperature are not suitable. In the contents of privy-vaults they soon die out (Koch). They are very easily killed by acids, mercuric chloride, and carbolic acid. According to observations by Koch they



FIG. 501.—Cholera-spirilla from a pure culture. Cover-glass preparation stained with fuchsin.  $\times 400$ .



FIG. 502. Stab-culture, in gelatin, of cholera-spirilla.

may live in well water for thirty days, in sewage for seven days, and on damp linen for three to four days. Nicati and Reitsch found them alive after eighty-one days in water taken from the harbor of Marseilles.

In cultures they sometimes form short rods, more or less curved (Fig. 501) and often joined in pairs; at other times they form long spirals. With these there also occur straight rods, and occasionally the majority form rods which show the curve only imperfectly or not at all. In fluid media to which oxygen has access they show active movements, which may be easily observed in hanging drops. According to investigations by Löffler the motility is dependent upon a terminal flagellum.

At a certain degree of exhaustion of the food-material there frequently appear involution-forms, in which the rods are sometimes shrunken, sometimes swollen, thus creating a great variety of forms. A globular swelling, as well as the formation of spots which do not take the stain in stained preparations, occur as the result of degeneration, and have often been erroneously interpreted as phenomena of fructification. Spore-formation has not been demonstrated. The addition of hydrochloric or sulphuric acid to cultures of cholera-spirilla in peptone-containing media (peptone-meat-infusion or an alkaline, one-per-cent. solution of peptone containing one per cent. of salt) causes the culture to assume a rose-red or Burgundy-red color, due to the formation of a coloring-matter, *cholera-red*. According to Salkowski, this is a nitroso-indol reaction.

When gaining entrance to the *intestinal tract of man* the spirilla, in so far as they are not destroyed by the action of the gastric juice or their growth otherwise prevented, develop both in the small and large intestines, and their multiplication is followed by a marked transudation from the intestinal mucosa, so that the intestine becomes filled with a fluid resembling meal-soup or rice-water, in which flakes of desquamated epithelium which has undergone mucoid degeneration float about.

The spirilla are always present in great numbers in the intestinal contents, and are found in the lumina of the intestinal glands, whence they may penetrate between and beneath the epithelial cells.

In recent cases the spirilla may usually be demonstrated in cover-glass preparations stained with methylene-blue or fuchsin. Fresh dejecta, as well as soiled linen, are suitable for the examination, since, according to observations made by Koch, the spirilla may multiply actively for some time upon moist linen and moist earth. In old cases the demonstration of the spirilla is more difficult but nevertheless succeeds in all cases, and is attainable most surely by means of plate-cultures. In order to facilitate the separation of cholera-spirilla from other intestinal bacteria, Schottelius recommends the mixing of the dejecta with double the amount of a slightly alkaline meat-infusion, and allowing the mixture to remain uncovered for twelve hours at a temperature of from 30°–40° C. The spirilla requiring oxygen will develop particularly upon the surface, and may be easily transferred thence to plate-cultures. Koch recommends for this purpose a solution of peptone with common salt.

The *presence of cholera-spirilla in the intestine excites an inflammation*, which in the beginning finds expression in redness, swelling, marked transudation, mucoid degeneration of the epithelium, and desquamation; later, by hæmorrhages, formation of sloughs, and ulceration. It is characterized constantly by a more or less marked cellular infiltration of the tissues. The solitary follicles and Peyer's patches are swollen even in fresh cases. Death may take place after a few hours or after one to

three days. If the disease lasts a longer time, the intestinal contents become more consistent and the intestinal mucosa shows ulcerative changes.

According to our present knowledge, the spirilla produce poisonous substances which cause local damage to the mucosa of the intestinal canal, and when absorbed give rise to symptoms of intoxication and cause paralysis of the vessels. Small foci of degeneration are often present in the liver and kidneys, within which the gland-cells show cloudy, fatty, or hyaline degeneration, or are necrotic. Moreover, the kidneys may frequently show cloudiness caused by a toxic degeneration of the epithelium; occasionally also a swelling of the cortex. Ecchymoses in the epicardium are of frequent occurrence, and in the later stages patches of necrosis may also occur in the mucous membrane of the vagina. The long-continued presence of spirilla in the intestine may give rise to ulceration. Finally, the spirilla may be crowded out by the putrefactive bacteria present in the intestine, and ultimately die out. Through the absorption of the products of decomposition a new intoxication may arise, which is not dependent upon the original spirilla.

According to Koch, Nicati, and Rietsch, cholera-spirilla may also be found in the vomitus. Nicati, Rietsch, Tizzoni, and Cattani found them also in the ductus choledochus and in the gall-bladder. According to the statements of these authors the spirilla usually do not enter the blood, but in cases of severe infection they may be spread throughout the body.

Koch demonstrated the presence of spirilla in a tank in India which furnished the inhabitants of the region with their entire supply of water for drinking and other purposes, at a time when a part of the inhabitants were sick and dying of cholera. Since then, they have often been demonstrated in water-supplies during cholera epidemics.

According to investigations by Nicati, Rietsch, van Ermengem, and Koch, symptoms resembling cholera may be produced in experimental animals through the introduction of cholera-spirilla into the intestinal canal. This experiment succeeds when cultures are introduced directly into the duodenum or small intestine (Nicati and Rietsch); as well as when the gastric juice of the animals (guinea-pigs) is neutralized with a five-per-cent. solution of soda, the bowels being quieted by an injection of 1 c.c. of tincture of opium to every 200 gm. of the body-weight, and one or more drops of a pure culture of the spirilla then introduced into the stomach (Koch).

The animals thus inoculated die with marked symptoms of collapse. The small intestine is found to be filled with a watery, flocculent, colorless fluid containing spirilla in great numbers; the intestinal mucosa is reddened and swollen.

Asiatic cholera is endemic in Lower Bengal and never entirely disappears there. Thence it spreads at times throughout India, and is carried by transportation over a larger or smaller part of the world. Since the spirilla are easily killed outside of the body the transportation must be effected mainly by individuals suffering from the disease. The infection probably occurs exclusively through the alimentary tract, as the result of the introduction of infected beverages, food, or some other substance into the mouth; but without doubt not every introduction of cholera-spirilla into the intestinal canal is followed by infection.

Moreover, it not infrequently happens that the spirilla increase in the intestine, but excite only slight changes, so that the infected individual

suffers no marked symptoms, and the diagnosis can only be made through the demonstration of spirilla in the stools.

If the cholera-spirilla get into the water-supply and there increase, cholera may develop in the given region with very great rapidity. If, on the contrary, the infection takes place by direct or indirect contagion from man to man, the spread is slow, in that the disease is confined to those who come into contact with the sick, or with articles contaminated by the latter. The incubation period is from one to two days.

In the intestines of convalescents the spirilla, according to investigations of Kolle, may live for a long time and multiply without giving rise to any symptoms betraying their presence. Kolle was able to demonstrate them in a number of cases after five to eighteen days, and in individual cases as long as twenty to forty-eight days.

One attack of cholera makes the individual immune for a certain time. The immunity depends upon the presence of bactericidal antibodies. Through these bodies the organism may be protected from cholera; but in those who have already contracted the disease the protective influence is of no avail (cf. § 32).

The poison which is produced by the cholera-bacillus and which causes the essential clinical symptoms of a cholera-infection is not known. *Gamaleia* believes that it is a nucleo-albumin; *Scholl* that it is a peptone (cholera-toxopepton). *Pfeiffer* is of the opinion that it is an element of the cell-body. According to *Metschnikoff* and others it is secreted by the cells. *Emmerich* and *Tsutoi* would refer the morbid symptoms of cholera to a nitrite poisoning, since nitrites in small doses cause retching, vomiting, discharge of thin-gruel faeces, fall of temperature, heart failure, cyanosis, and cramps of the extremities and muscles of the neck—that is, symptoms resembling those of cholera—and, moreover, because the cholera-spirilla are able to form nitrites out of nitrates (contained in the food).

The virulence of cholera-cultures differs greatly, according to the place of origin and the age. The virulence decreases with the age. Guinea-pigs which are very susceptible to intraperitoneal inoculations of cholera may be protected against this infection by the intraperitoneal injection of attenuated cultures; but no absolute immunity can be produced in this way. The blood-serum of human individuals that have recovered from an attack of cholera shows protective properties for guinea-pigs for several weeks after the attack.

The nitroso-indol reaction in cultures of the cholera-spirilla is due to the fact that the cholera-spirillum in peptone solutions not only forms indol but also nitrites. The addition of hydrochloric or sulphuric acid sets free nitrous acid which forms a red color with indol. With the *Spirillum* of *Finkler*, the *Spirillum* of *Metschnikoff*, and the *Spirillum* of *Deneke*, which also produce indol, the red color of the cultures occurs only when potassium nitrite is added with sulphuric acid, or when nitrous acid alone is added.

#### *Spirilla Resembling the Cholera-spirillum.*

(1) The *Spirillum* of *Finkler* and *Prior*, found by these observers in the dejecta of persons suffering from cholera-nostras, after the discharges have stood for some time in a vessel. The spirilla are very similar to the cholera-spirilla, only somewhat longer and thicker. In plate-cultures they are distinguished from the latter only in the fact that the small colonies are not distinctly granular and have a sharp contour. Gelatin is quickly, not slowly, liquefied; and consequently in stab-cultures after twenty-four hours a sac-like tube filled with cloudy fluid (Fig. 503) is formed, which soon reaches the walls of the tube.

On potatoes (*Flügge*), even at room temperatures, they form within forty-eight hours a grayish-yellow, slimy coating, sharply marked off from the substance of the potato by a whitish border; while cholera-spirilla do not grow at all at room-temperature, and at higher temperatures form brown coatings.

Further, they cause a foul smelling decomposition; and are rather resistant to drying. When introduced into the intestine of guinea-pigs by the method given above, they produce effects similar to those caused by cholera-spirilla, but less intense.

It is very doubtful whether the *Spirillum* of *Finkler* and *Prior* possesses a pathogenic significance for cholera-nostras, since the dejecta from which these investigators



obtained their cultures were not fresh; and other authors have failed to find the spirilla in corresponding cases (*Kartulis*, "Zur Aetiologie der Cholera nostras," *Zeitschr. f. Hyg.*, vi., 1889). *Knisl* (*Münchener ärztliches Intelligenzblatt*, 1885), on the other hand, found them in the cæcal contents of a suicide.

(2) *Spirillum tyrogenum*, found in cheese by *Deneke* in *Flügge's* Institute (*Deut. med. Wochenschr.*, 1885), is also very much like the cholera-spirillum, but is somewhat smaller, and the long spiral threads are more closely wound. Cultures on gelatin-plates form at first sharply contoured discs that by low magnification appear dark, and liquefy the gelatin more rapidly than the spirillum of Koch. In stab-cultures they behave like the Finkler-Prior spirillum, but do not grow upon potato.

(3) *Spirillum sputigenum* is a spirillum of the shape of a curved rod, somewhat longer and thinner than the cholera-spirillum. It occurs in the saliva, and cannot be cultivated upon the ordinary media.

(4) *Vibrio of Metschnikoff* (*Gamaleïa*, "Vibrio Metschnikovi et ses rapports avec le microbe du cholera asiatique," *Annal. d. l'Inst. Past.*, ii., 1888; iii., 1889; *Pfeiffer*, "Ueber den Vibrio Metschnikovi und sein Verhältniss zur Cholera asiatica," *Zeitschr. f. Hyg.*, 1889) is a fission-fungus isolated by *Gamaleïa* in an epidemic occurring in chickens in Odessa, which was characterized by diarrhœa and enteritis. When cultivated it shows a very great resemblance to the cholera-spirillum of Koch. The spirillum is most easily obtained pure by inoculating pigeons with the blood of diseased chickens. The pigeons die in from twelve to twenty hours and show the spirilla in the blood and in the intestinal tract.

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FIG. 503. — Stab-culture, in gelatin, of the *Spirillum* of Finkler and Prior.

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§ 176. The *Spirochæte Obermeieri* (Fig. 504) is found constantly in the blood of patients suffering from **relapsing fever** during the attacks of the fever, and the multiplication of these organisms in the body is the cause of the disease.

The spirochæte is 16–40  $\mu$  long, and possesses numerous spiral turns. In a fresh drop of blood it shows very active motion. Carter and Koch succeeded in producing the disease in apes by inoculation with the spirochæte; but nothing definite is known of its mode of development and habitat outside of the blood. The whereabouts of the spirochæte or of its spores during the afebrile stages of the disease are not known. The subcutaneous inoculation into apes of blood containing the spirochæte is followed only after several days by an attack of fever, and the spirochæte is found in the blood only during the febrile stage. According to the autopsy-findings observed in man, the spleen is swollen and contains numerous yellow foci of degeneration, and often also anæmic infarcts.

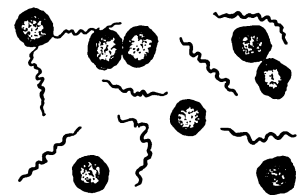


FIG. 504.—*Spirochæte Obermeieri* from the blood of an individual ill with relapsing fever. After a dried preparation stained with methyl-violet.  $\times 475$ .

According to investigations by Nikiforoff the histological examination of the spleen shows extensive cell-necrosis and cell-degeneration (Fig. 505, c), as well as deposits of fibrin in the veins of the pulp, and proliferative processes in the pulp-cells. Further, numerous large pulp-

cells (*f*) enclose red and white blood-cells or the remains of such. Finally, numerous spirilla are found, especially in regions which are not

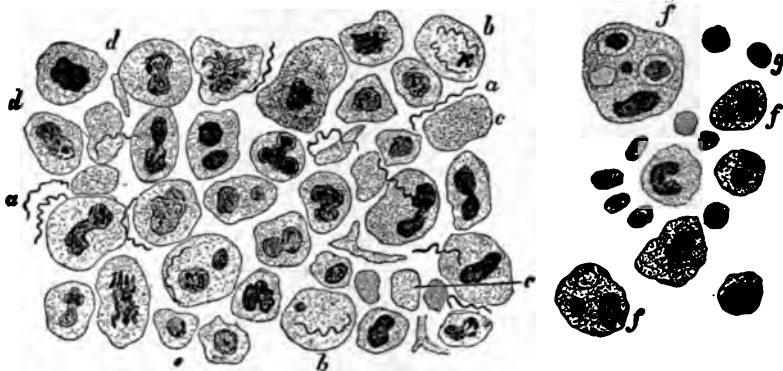


FIG. 505.—Portion of tissue and isolated cells from a splenic follicle with partial necrosis, in relapsing fever. (After Nikiforoff.) (Potassium bichromate and sublimate, methylene-blue.) *a*, Free spirilla; *b*, lymphocytes with spirilla; *c*, non-nucleated lymphocytes; *d*, large, *e*, small mononuclear pulp-cells; *f*, phagocytes enclosing leucocytes and red blood-cells and their remains; *g*, free red blood-cells.  $\times$  about 600.

wholly necrosed but contain degenerated and necrotic cells, in part free (*a*), and in part enclosed in leucocytes (*b*), partly well-preserved, and partly beginning to show disintegration.

The spirochaetes stain especially well, in cover-glass preparations, with alkaline methylene-blue and fuchsin.

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## CHAPTER XI.

### The Yeasts and Moulds, and the Diseases Caused by Them.

§ 177. The **yeasts** (**Blastomycetes**) and the **moulds** (**Hyphomycetes**) belong, as do the schizomycetes, to the non-chlorophyllaceous thallophytes. With the schizomycetes they have no phylogenetic relationship; on the other hand, they are closely related to one another.

The moulds and yeasts, like the schizomycetes, derive their nourishment from organic substances containing carbon. The majority find their food in dead organic substances, and belong therefore to the *saprophytes*; some are able to obtain nourishment from living tissues, and are to be classed, at least at times, with the *parasites*. In human beings both forms occur.

Outside the organism the moulds are generally known as the producers of the different mouldy films which so frequently develop upon organic substances. They belong to different groups of fungi.

The yeast-fungi are the cause of alcoholic fermentation, and form the scum on the top of alcoholic beverages.

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§ 178. **Yeasts** occur in man in the form of *naked* or *encapsulated*, *oval* or *round cells* of varying size. They are found chiefly as harmless **saprophytes**, most frequently in the upper part of the intestinal canal—in the stomach—where they are almost constantly present; and when beverages in the process of alcoholic fermentation are taken they may occur in large numbers, and may also multiply. In the bladder they may likewise multiply, in case the urine contains sugar; and may cause fermentation of the urine with evolution of carbonic-acid gas.

As **parasites** no importance has been attached to them until very recently, but the investigations of Busse, Buschke, Sanfelice, Curtis, and



others have established the fact that there are also *species of Saccharomyces of pathogenic importance*. According to these observations the pathogenic yeasts can multiply in different tissues, in the skin, periosteum, lungs, and glandular organs, and can excite either *purulent inflammations*, or *proliferations of granulation tissue*, which run a course similar to that of an infection with actinomycosis or tuberculosis. In inflammatory foci the yeast cells are for the chief part provided with a capsule. They may be present in large numbers so that through their mass alone they may give rise to tumor-like swellings. Through degenerative changes, crescentic forms may develop from the oval yeast-cells.



FIG. 506.—*Saccharomyces ellipsoideus*.  $\times 400$ .

In solutions containing sugar the blastomycetes form oval cells (Fig. 506). Reproduction takes place through budding and constriction; on any portion of the parent cell there may develop an excrescence, which is constricted off after it reaches the size of the mother cell. Under certain conditions the cells may grow out into threads, but in these threads no subsequent segmentation occurs; jointed threads arise through budding (Cienkowski, Grawitz). A dilute culture-medium favors the formation of threads.

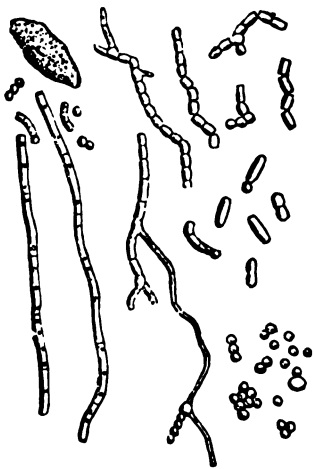


FIG. 507.—Fresh favus-mass consisting of hyphae, conidia, and epithelial cells. (After Neumann.)

**Mould-fungi** are found in man partly in the form of simple or branched, unjointed or jointed threads of varying thickness; and partly as oblong or even as spherical cells. The threads are designated as **hyphae** (Figs. 507, 508), and the mass which they form as **mycelium**; the spherical or long oval or short cylindrical cells, which are frequently arranged in the form of a rosary, as **spores**, or better as **conidia-spores** (Figs. 507, 508). Only rarely has there been observed within the body a fructification upon special fruit-organs.

The moulds are partly **saprophytes** and partly **parasites**; and are found almost exclusively in regions accessible from without, as the skin, intestinal canal, respiratory tract, external ear, vagina, etc. Only exceptionally, and under especial conditions, do they reach the internal organs, as, for example, the brain. It is evident that, on the whole, the living tissues of the human organism do not afford a suitable nutrient medium for the mould-fungi, and the life-activities of the tissue-cells for the greater part do not permit their development and multiplication. The need for oxygen prevents the growth of moulds in many tissues; and for many moulds the temperature of the body is too high. Moreover, the chemical composition of the tissues does not offer to the moulds a favorable mixture of nutrient material.



FIG. 508.—From a deposit of aphthae, on the tongue of a man dying of typhoid fever.  $\times 275$ .

**Moulds growing as saprophytes** occur in man most frequently in the alimentary canal, particularly in the *mouth*, *pharynx*, and *oesophagus*. They develop in these regions particularly when the ingesta or desquamated cells lie undisturbed in one position for a long time, and when the function of the organ concerned is lowered. They are recognized through the formation of hyphæ and conidia.

In the external *auditory canal* moulds grow especially in abnormal masses which fill up the passage and consist in part of cerumen, or of inflammatory exudates and desquamated cells, and in part of substances introduced from without.

In the *lungs* moulds are occasionally found upon the necrotic wall of cavities, particularly those due to tuberculosis, as well as in necrotic and gangrenous hæmorrhagic infarcts, etc. In the air-passages they are observed most frequently in bronchiecstases.

In the alimentary tract, as well as in the ear and lungs, the moulds form chiefly a whitish deposit on or in the tissues. In the event of fructification upon especial fruit-bearers they may take on a brown, gray, or even black appearance. In the intestinal canal the food and drink may give them various colors.

At first the moulds grow in dead material, but they may penetrate thence more or less extensively into living tissue; and cases have been observed in which they have even entered the circulation and have been



FIG. 509.—Section through an aphthæ-covered oesophagus of a small child (alcohol, carmine, Gram's). *a*, Normal epithelium; *b*, connective tissue; *c*, swollen and desquamated epithelium infiltrated with fungus-threads; *d*, epithelium infiltrated with cells; *e*, cocci and bacilli; *f*, cellular focus in the connective tissue.  $\times 95$ .

carried by the blood-stream to distant organs. Thus the fungous growth called **thrush** (*aphthæ*, *muguet*), which appears chiefly upon the mucous membrane of the *mouth*, *pharynx*, and *oesophagus*, and more rarely upon that of the *stomach*, *intestine*, and *vagina*, and upon the *nipples* of nursing women, cannot be regarded as a pure saprophytic, but, on the contrary, is a **parasitic growth**, which penetrates into living epithelium (Fig. 509, *c*), and even into the underlying connective tissue. It is true, however, that thrush occurs chiefly in infants and in debilitated invalids who are no longer able to cleanse the mouth, throat, and oesophagus, so that some especial local predisposition appears to be necessary for its development, and it is probable that the primary colonization of the fungus takes place in dead material. Nevertheless, there occurs then an

active penetration into living tissue—that is, first into the epithelium (*c, d*), but often also into the connective tissue (*a, f*), and into the blood-vessels, and from these portals of invasion there may develop metastases in the internal organs. Thus, Zenker has observed hyphæ and conidia in an abscess of the brain; and Paltauf has reported a case in which a mould-fungus was conveyed from an intestinal ulcer to the brain and lung. Schmorl has described thrush-metastases in the kidneys.

Moreover, **growths of moulds in the lungs** are not always confined to dead material or to the cavity of the bronchus, but it happens, though rarely, that they penetrate into the living respiratory parenchyma, forming small white or yellowish, nodular masses, within which the lung tissue is necrotic, while in the neighborhood there is formed an inflammatory infiltration. In the injured *cornea* they may likewise penetrate into the tissue and cause necrosis and inflammation.

**Local colonizations of moulds which penetrate into living tissue** cause a more or less marked irritation of the surrounding tissues, and give rise to *tissue-degenerations* (Fig. 509, *c*) and *inflammation*. Such changes may be observed in mycosis of the lung, as well as of the intestine (*c, d, f*) and ear. When invading the lungs they form growths of hyphæ which resemble the granules of actinomycosis, and are surrounded by collections of cells. Their action, however, is always limited, and they produce no substances which are injurious to the organism as a whole, or cause symptoms of poisoning. The frequently reported finding of moulds in abscesses of the subcutaneous tissues and internal organs are probably to be interpreted as due to the fact, that along with the bacteria causing the suppuration, moulds also get into the tissues, as well as into the circulation. A general spreading of mould-fungi does not occur in these cases, in that the further development of the same is confined to the place of the metastasis.

The form of moulds which are saprophytic, or to a limited extent parasitic, in man, belong to the *Mucor*, *Aspergillus*, and *Eurotium* genera. From the ear various species have been obtained: *Aspergillus fumigatus* (Fresen), *Aspergillus flavus* or *flavescens* (Brefeld, Wreden), *Aspergillus niger* or *nigricans* (Van Tieghem, Wreden, Wilhelm), *Aspergillus nidulans* (Eidam), *Eurotium malignum* (Lindt), *Mucor corymbifer*, and *Trichothecium roseum*; and, in so far as known, these are the same species which occasionally occur in the respiratory tract.

In the majority of cases it is necessary, in order to determine the variety of mould, to make cultures upon suitable nutrient media (decoction of bread, bread-agar, potato, gelatin, etc.). On these the conidia which are sown grow out into germ-tubes, and form simple or branched, unicellular or multicellular threads, on which arise the peculiarly constructed fruit-bearers characteristic of the species, which eventually produce conidia. Many also form spores through the copulation of cells of the mycelia, especially when the supply of oxygen is lowered (Brefeld, Siebenmann).

In the mucors there appear especial *fruit-bearers* (Fig. 510, *c*), which according to the species are either single or branched, and on the ends of which there are knob-like swellings from which the *sporangia* (*d*)—that is, spherical vesicles filled with conidia-spores—grow.

*Mucor corymbifer*, for example, forms branched fruit-bearers (Fig. 509, *c*). The sporangia (*d*) on the ends possess a smooth membrane and enclose at the time of ripening yellowish conidia-spores.

The aspergilli form *conidia-bearers*, which swell out spherically above, and then produce numerous *sterigmata*—that is, cone-like outgrowths,

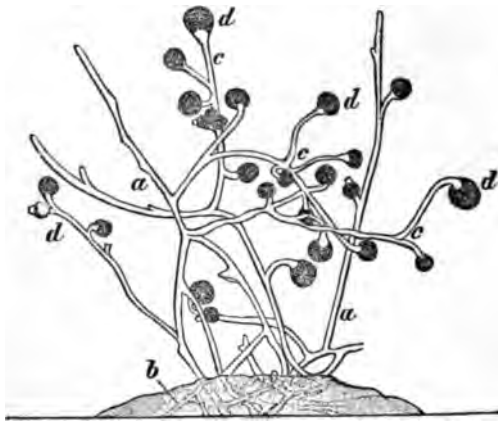


FIG. 511. — *Mucor corymbifer* in fructification (culture upon glass-slide). a, Aerial hyphae; b, mycelia lying within the nutrient gelatin; c, branching fruit-bearers; d, sporangia.  $\times 100$ .

radially arranged, thickly crowded, and sprouting out from the upper half of the sphere. From each sterigma a chain of *conidia* is later constricted off (Fig. 511, a, b).

The botanical position of the fungus of thrush (*aphthæ*) is still unsettled. Formerly it was called *Oidium albicans*, and classed with the family *Oidium*, which occurs in different species in the form of filmy coatings upon organic substances. When cultivated from conidia it produces hyphae which become jointed and develop conidia through a transverse division of the threads, but form no peculiar fruit-bearers.

According to Rees, Grawitz, Kehrér, the thrush-fungus grows by budding and by the production of mycelia and conidia, which in turn produce at their ends, by a process of constriction, new conidia, in a manner similar to that which takes place in the forms of *mycoderma* belonging to the yeast-fungi. Consequently this fungus should be designated *Mycoderma albicans*. Linossier and Roux are, however, of the opinion that the thrush-fungus does not belong at all to the *saccharomycetes*, and they regard its classification at the present time as impossible. Cao, who has investigated numerous varieties of *oidium*, regards the *oidia* as a well-defined class of fungi standing between the *blastomycetes* and the *hyphomycetes*, which they approach through their production of mycelia.

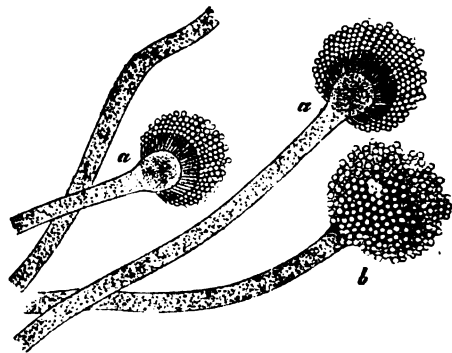


FIG. 511. — Hyphae with conidia-bearers of *Aspergillus fumigatus*. a, Fruit-head in optical cross-section; b, fruit-head seen from above.  $\times 275$ .

According to Plant the thrush-fungus is identical with a mould, *Monilia candida*, which occurs frequently in nature. Kehrér suspects that it is one of the higher moulds which has become degenerated through parasitism.

According to Neumayer all varieties of yeasts are resistant to the digestive juices, and may pass through the human intestinal tract without being killed. Without the coincident introduction of some fermentable substance they are harmless. They exert an influence upon the intestinal canal only when fermentable substances are introduced, whereby at the high temperature of the body abnormal products of fermentation are produced having an irritating action upon the intestinal tract.



*Busse* found (1894) great numbers of yeast-cells developing in the diseased areas present in a woman, thirty-one years of age, who died from multiple inflammations of the bones, skin, lungs, kidneys, and spleen, partly tumor-like and partly abscess-forming. According to his findings it may be regarded as certain that the yeast was the cause of the disease. The yeast could be easily cultivated upon suitable media. Mice were particularly susceptible to inoculation, dying in from four to eighty-three days after the injection. At death the yeast-cells were found to have markedly increased both at the point of inoculation, and also in the internal organs. A proliferation of tissue occurred only after a long duration of the infection.

*Buschke* found yeasts in multiple ulcers of head and neck, arising from acne-like lesions. *Gilchrist* and *Stokes* found yeasts in a lupus-like affection of the skin.

*Sunfelice* experimented with yeasts from fruit-juices, and found among these one pathogenic for guinea-pigs (*Saccharomyces neoformans*) and one pathogenic for chickens and dogs (*Saccharomyces lithogenes*). *Curtis* found, in multiple proliferations of the skin resembling myxosarcoma, yeast-cells which were pathogenic for rats, mice, and dogs.

*Sunfelice*, *Corseili*, *Frisco*, *Roncali*, *Binaghi*, *Leopold*, and others believe that blastomycetes may be the cause of true tumors, sarcoma and carcinoma; but true tumors have never yet been produced experimentally by inoculations of yeast-cells or by injections of the same into the blood. Only suppurations and inflammatory tissue-proliferations have been produced by such experiments; and the finding of yeast-like structures in true tumors, even if part of these were true yeast-cells, does not permit of the conclusion that tumors are caused by yeasts (cf. § 122).

According to investigations by *Koch*, *Löffler*, *Lichtheim*, *Hückel*, and *Lindt*, the conidia of *Aspergillus fumigatus*, *A. flavescens*, *A. nidulans*, *Eurotium malignum*; *Mucor rhizopodiformis*, *M. corymbifer*, *M. pusillus*, and *M. ramosus*, grow at the body-temperature, and, when introduced into the blood-current of animals, grow into the tissues and form hyphæ, although there is no new formation of conidia, and consequently no progressive infection of the animal extending beyond the area within which the spores have been introduced. Conidia of *Mucor rhizopodiformis* and *M. corymbifer* grow, when introduced into the blood-stream of rabbits, chiefly in the kidneys and the lymphatic apparatus of the intestines, where they cause a hæmorrhagic inflammation. According to *Cao*, there are different species of oidia which, when injected into rabbits, cause inflammations, abscesses, or proliferations of granulation tissue; and many produce also a toxic action upon the organism.

**Aspergillus mycoses of the respiratory tract** are not rare in animals, especially in birds, and the proliferating mycelia cause tissue-necrosis and inflammation. According to *Chantemesse*, *Aspergillus fumigatus* causes in pigeons diseased conditions of the mouth, lungs, liver, and kidney, that of the first two organs resembling diphtheria, that of the latter two closely resembling tuberculosis. It may, therefore, be designated *pseudotuberculosis aspergillina*. According to *Potain* the infection may be transmitted to man and give rise to ulcerative diseases of the lung.

*Eurotium* and *Aspergillus*, according to *Siebenmann*, are two different families, having, however, a close resemblance to each other, in that the mycelia and conidia are similarly formed. The essential differences between the two lie in the fact that *Eurotium* forms perithecia in the form of shining, light-yellow or sulphur-yellow, translucent bodies the size of a grain of sand, delicate and easily crushed; while the true *Aspergillus* forms hard, woody sclerotia usually embedded in a thick, white matted mass of mycelia. The development of these takes place in two periods. The second part of the development occurs only when the sclerotium finds a lodgment upon a moist substratum.

*Aspergillus flavus* of *Brefeld* (*Eurotium Asperillus flavus* of *de Bary*) forms golden yellow, green, and brown growths; round, yellow, olive-green, or brown fruit-heads; round, rarely oval, sulphur-yellow to brown conidia with minute warts on the surface; diameter 5-7  $\mu$ . *Aspergillus fumigatus* of *Fresen* (*Aspergillus nigrescens* of *Robin*) forms green, bluish, or gray growths; the fruit-heads are long, in shape resembling an inverted cone; conidia, round, rarely oval, smooth, mostly clear and colorless; diameter 2.5-3  $\mu$ . *Aspergillus niger* of *Van Tieghem* (*Eurotium Aspergillus niger* of *de Bary*) forms dark chocolate-brown growths; conidia are round, brownish-black, or grayish-brown when ripe; surface smooth or warty; diameter 3.6-5  $\mu$ .

*Aspergillus* can develop upon the injured cornea and give rise to purulent inflammation. *Leber* (*Graefe's Arch.*, xxv.) cultivated it upon the cornea and in the anterior chamber of the eye of the rabbit. Finally, *Aspergillus* also appears in the pelvis of the kidneys. *Bübes* (*Biol. Centralbl.*, ii.) found the conidia and hyphæ of a mould in ulcers of the skin which were covered by scabs, and gave to it the name of *Oidium subtile cutis*.

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§ 179. **Thread-fungi** are to be regarded as the **exciting cause of disease** in certain **affections of the skin**, as *favus*, *herpes tonsurans*, *pityriasis versicolor*, *erythrasma*. In all of these diseases the epithelial parts of the skin contain colonies of hyphæ and conidia, and there remains no doubt that their presence causes in part tissue-degenerations, and in part proliferations and inflammations.

The **fungus of favus** (Fig. 507) is usually called **Achorion Schönleinii** (discovered by Schönlein in 1839).

**Favus** (*tinea favosa*, *scald-head*) affects particularly the hairy portions of the head, more rarely other regions, as, for example, the substance of the nails. It is characterized by the formation of **discs** (*favus scutula*), varying in size from that of a lentil to that of a five-cent piece, of a sulphur-yellow color, and indented or pierced by a hair. In an abortive course it may merely form scales similar to those of herpes.

According to Kaposi, the favus scutulum originates as a small, punctiform, yellow focus lying under the epidermis and penetrated by a hair. This grows in a few weeks to the size of a lentil and then forms a sulphur-yellow, indented disc showing through the upper layers of the skin. The scutulum consists of hyphæ and conidia spores, and lies in a cup-shaped depression of the skin, beneath the horny layer which is drawn away above it. If the mass be removed during life, the cavity shows a red moist surface. The favus itself forms a white, crumbling mass which is easily disintegrated in water.

If the scutula are not removed, they join together to form larger masses. When the epidermis is desquamated the favus-mass becomes exposed and dries up into a yellowish-white, mortar-like material. The hairs appear lustreless, as if covered with dust, and are easily pulled out, since the mycelia and conidia of the fungus penetrate into the hair-shaft and hair-bulb, as well as into the sheath of the hair-root.

Through the growth of the fungus-masses the hairs may not only be shed, but the papillæ may become atrophic. At the same time there is produced in the neighborhood of the hair-follicle a more or less intense inflammation which may take on an eczematous character.

The development of achorion in the nails (*onychomycosis favosa*) gives rise to sulphur-yellow deposits or uniform thickenings of the parenchyma of the nails with simultaneous loosening and cheesy disintegration of the same.

**Trichophyton tonsurans**, the fungus of **herpes tonsurans** ("barber's itch," "ringworm"), consists of long narrow threads, branching but little, and with few conidia. It forms no scutulous masses, but penetrates easily into the hair-shaft, and makes the hairs brittle. It shows certain differences of growth, according to whether the herpes develops upon hairy surfaces or upon areas devoid of hairs.

*Herpes tonsurans capilliti* forms bare discs varying in size from that of a five-cent piece to that of a dollar. These spots in which the hairs are broken off short look like places in which the hair has been badly shaven. The surface is smooth or covered with scales, and somewhat reddened at the border of the disc. If the fungus-threads penetrate into the hair-follicles, pustules and scabs are formed. Such discs may appear in many places, and may constantly increase in size until healing finally takes place.

On places devoid of hairs the herpes forms vesicles (*Herpes tonsurans vesiculosus*), and red scaly spots, discs, and circles (*Herpes tonsurans squamosus*). At times red spots appear in numerous places; these quickly spread, and as rapidly heal. The fungus is found between the uppermost layers of the epidermis, just beneath the stratum corneum (Kaposi).

If trichophyton develops in the nail, the nail becomes cloudy, scales off, and is easily broken—a condition designated as *onychomycosis trichophytina*.

*Sycosis parasitaria* arises through the fact that the development of the fungus is accompanied by a severe inflammation of the hairy parts of the skin, leading to infiltration and suppuration—that is, to the formation of pustules, abscesses, and papillary proliferations. According to Kaposi and others **eczema marginatum** is also caused by the trichophyton tonsurans. The condition occurs in those regions where two surfaces of skin come into contact with each other and are macerated by sweat; and is characterized by the formation of vesicles, pustules, and scabs, which are situated in the periphery of a pigmented surface.



*Microsporon furfur*, the fungus of **pityriasis** or **mycosis versicolor** or **dermatomycosis furfuracea**, occurs likewise in the form of hyphæ and conidia, which are somewhat smaller than those of other skin-fungi. The pathological changes produced by this fungus are characterized by the formation of pale yellow or yellowish-brown to dark-brown and brownish-red spots, varying in size from that of a lentil to that of the hand, sometimes smooth and shining, at other times dull and exfoliating, and of irregular shape. They may be spread uniformly over large areas of skin; and are found chiefly upon the trunk, neck, and flexor surfaces of the extremities, but never upon the hands, feet, or face.

*Microsporon minutissium* is the name given to a thread-fungus, which is found in the skin affection known as **erythrasma** (von Bärensprung). The disease is characterized by the formation, on the inner side of the thigh, of brown or reddish-brown patches, which are only slightly scaly, and may be as large as the palm of the hand. The fungus is found in the epidermis, and is smaller than that of pityriasis.

The thread-fungi occurring in the diseased areas of the skin may be cultivated upon proper media (agar-agar, agar-glycerin, gelatin, potatoes, blood-serum, etc.), and on such the conidia develop into single and branching threads, which become jointed (Fig. 512, *a*), and form chains of short cell (*b*). Club-like formations which frequently appear upon the ends of the threads in cultures, are regarded by Quincke and Elsberg as imperfect sporangia. The botanical position of these fungi is not yet determined; and nothing is known with certainty concerning their distribution outside of the human and animal body.

According to Quincke, three forms of fungi occur in favus-masses, two of these being varieties of one species of fungus. Elsberg found only two, which he regards as being varieties of the same species. Pick, Plaut, and Biro believe firmly in the etiological unity of favus.

Sabouraud advances the view that the fungi causing trichophytosis represent very different species, all of which belong to the genus *Botrytis*. Kröning distinguishes three groups of trichophyton-fungi according to the different appearances of the cultures on potato, and emphasizes, moreover, the differences in their organs of generation and fructification. Rosenbach, who has studied the moulds occurring in deep suppurating inflammations of the skin, differentiates several trichophyton-fungi as the cause of these affections.

According to Spietschka the *Microsporon furfur* may be cultivated from the scales of the skin, and in cultures can be very well differentiated from the other pathogenic thread-fungi. Through the inoculation of the fungus a typical mycosis may be produced in man.

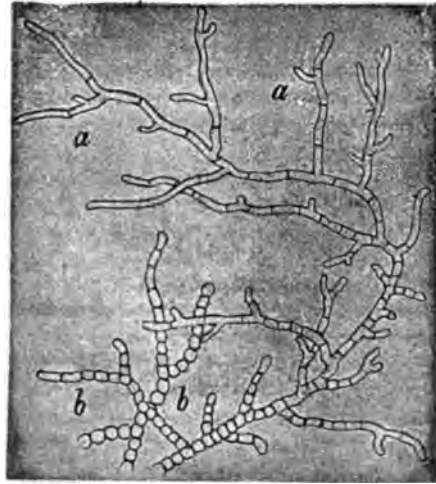


FIG. 512.—Culture of *Trichophyton tonsurans*. *a*, Branching threads with long joints which have delicate walls; *b*, threads with thick-walled, short segments, some of them being spherical.  $\times 370$ .

From the great number of recent investigations by various writers it is impossible to deduce anything definite concerning the number of kinds of favus- and trichophyton-fungi. It is, however, evident from these investigations that the nature of the nutrient medium is of great influence on the character of the growth (Sabouraud, Waelsch), and the difference in findings is to be referred in a great measure to differences in the nutrient media on which the moulds were grown.

Inoculations with fungi grown in cultures, into the skin of human beings, rabbits, mice, etc., which were made by Grawitz, Boer, Münnich, and others, gave partly negative, partly positive results. According to Plaut the inoculations never give positive results when spore-formation has already taken place in the cultures.

Von Hebra has described (*Wiener med. Blätter*, 1881; "Die Krankh. Veränd. d. Haut," Braunschweig, 1881) as *dermatomycosis diffusa flexorum* a peculiar itching dermatosis, which occurs on the elbow and bend of the knee, and is thought to be caused by fungi, which are like those of *pityriasis versicolor*.

*Favus* and *herpes tonsurans* occur also in **domestic animals**, as well as in *mice* and *rats* (cf. Friedeberg and Fröhner, "Lehr. d. spec. Pathologie der Haustiere"). Waelsch inoculated human individuals with favus-fungi, which he had cultivated from mice affected with favus, and obtained typical favus scutularis.

Intravenous injections of favus-fungi into rabbits (Bukovsky) produced in the lungs of these animals a form of pseudotuberculosis; and cellular nodules are found in which fungus threads have developed in a manner suggesting the lesions of actinomycosis. After a time the fungi die.

In **invertebrate animals** there not infrequently occur diseases produced by mycelium-fungi. Thus *Botrytis Bassiani* causes the so-called *muscardine* in silkworms; *Cordyceps militaris* destroys the injurious pine-spider *Gastropachia pini*; *Turichium megaspermum*, a black-colored fungus, kills the destructive earth-caterpillar *Agrotis segetum*. Fungi belonging to the family *Empusa* attack especially the caterpillars of the cabbage-butterfly (*Empusa radicans*), and the house-fly (*Empusa muscae*), their mycelia growing all through the caterpillar and finally killing it. *Achylya prolifera*, according to Harz (*Jahresber. d. Münchener Thierarzneischule*, 1882-83), grows through the musculature of crayfish, and is the cause of the crayfish-pest.

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## CHAPTER XII.

### The Animal Parasites and the Diseases Produced by Them.

#### I. Protozoa.

§ 180. Of the **Protozoa** occurring as parasites in man, only a small number was known up to a few years ago; and even the known forms possessed but slight significance, since there could be ascribed to them



FIG. 513.—*Amoeba coli mitis*. (After Roos.) *a*, Free motile amoebæ; *b*, encysted amoebæ.  $\times 500$ .

no marked influence upon the tissues. Through the investigations of the last few years, however, different forms have been recognized as the cause of morbid processes; and it is quite possible that there are still other protozoa capable of exciting pathological changes in the human body. The forms already recognized are representatives of all four classes of protozoa.

Of the **Rhizopoda** there occur in the intestine three amoebæ, known as the *Amoeba coli vulgaris*, the *Amoeba coli mitis* (Roos, Quincke), and the *Amoeba dysenteriae* (Kartulis, Osler, Councilman, Lafleur, Kruse, Pasquale). The *Amoeba dysenteriae* is certainly distinguishable from the other two, while the *Amoeba coli vulgaris* and the *Amoeba coli mitis* resemble each other very closely, and may possibly be identical.

The *Amoeba coli vulgaris* is a harmless intestinal parasite which is not infrequently present in the intestine (Roos, Kruse, Pasquale). The *Amoeba coli mitis* was observed by Roos and Quincke in cases of chronic enteritis in patients who had always lived in North Germany.

The *Amoeba coli mitis* consists, according to Roos, of a protoplasmic cell-body, from  $25\text{--}35\ \mu$  in diameter (in the spherical condition). It exhibits slow movements, and very frequently encloses foreign bodies, for example, bacteria and food-remains (Fig. 513, *a*). Besides the motile form, there occur, according to Roos, also encysted, spherical forms which are surrounded by a double-contoured membrane, and enclose clear, round vesicles in their interior (Fig. 512, *b*). When fed to animals (cats) no pathogenic properties are disclosed.

The *Amoeba dysenteriae* (identical with the *Amoeba coli* described by Loesch) has a diameter, according to Roos, of from  $15\text{--}25\ \mu$ , but according to Kruse and Pasquale, from  $10\text{--}50\ \mu$ . In the cell-body there may be recognized a homogeneous ectoplasm and a variable granular entoplasm, the arrangement of which varies according to the form of the animal (Fig. 514, *a*). By staining, a nucleus may be made visible within the cell. The cells are capable of active movement, and assume thereby the most varied shapes (*d*). They very often contain foreign bodies, particularly red blood-cells or remains of such (*b*), or are studded with



clear vacuoles (c). According to Roos, they may also become encysted (e).

According to investigations by Koch, Kartulis, Kruse, and Pasquale, they are invariably present in the dysentery prevailing in Egypt, and are usually also demonstrable in the dejecta. They have also been observed in cases of dysentery in Russia (Loesch, Massiutin), in America (Osler, Councilman, Lafleur, Lutz, Dock), in Germany (Roos), and in Austria (Kovacs). According to investigations by Kartulis, Councilman, Lafleur, Kovacs, Roos, Kruse, Pasquale, and others, it cannot be doubted that they are of some significance in the origin of certain forms of dysentery. It is only questionable whether they alone, or only with the aid of changes produced by bacteria, are able to bring about pathological changes. In support of the latter theory is the fact that, when present in the tissues, they are always accompanied by bacteria.

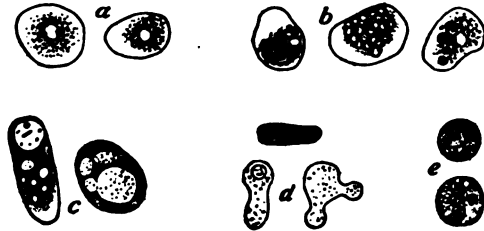


FIG. 514.—*Amœba dysenteriae* sive *Amœba coli felis*. (After Roos.) a, Amœbæ without inclusions; b, amœbæ containing blood; c, amœbæ with large vacuoles in their protoplasm; d, young forms; e, encysted forms.  $\times 665$ .

**Amœbic dysentery** is characterized by the occurrence of a hæmorrhagic catarrh, and by the formation of circumscribed ulcers with undermined edges. The amœbæ (Councilman, Lafleur, Roos, Kruse, Pasquale) increase not only in the intestinal mucosa, but also penetrate into the mucosa and submucosa, and there form large colonies, in the region of which the tissue undergoes necrosis without the formation of any large amount of exudate. By the rupture of the submucosal foci through the mucosa there are formed ulcers with undermined edges, which, gradually increasing in size, may attain large dimensions.

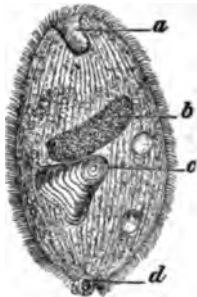


FIG. 515.—*Balantidium* (*paramœcium*) *coli*, with two contractile vacuoles. (After Claus.) a, Mouth; b, nucleus; c, included starch grains; d, foreign body in the act of being extruded. High magnification.

If *abscesses of the liver* arise during the course of an amœbic dysentery, these may also contain the amœbæ in addition to bacteria; and it may be assumed that the former also take part in the destruction of the liver tissue.

The amœbæ of dysentery are pathogenic for cats, and, when fed to them or when introduced into the rectum of the animal, cause a rapidly progressive, often fatal dysentery, which is similar in all respects to amœbic dysentery in man. The amœbæ also penetrate into the mucosa and submucosa of these animals.

Of the Infusoria, both *flagellated* and *ciliated* forms occur in man. Of the latter form the best known is the *Paramœcium* or *Balantidium coli* (Fig. 515). This is a large infusorium thickly set with ciliæ, which has been demonstrated many times in the large intestine and in the dejecta in cases of diarrhœa, and

may stand in a causal relation to the intestinal catarrh. Of the flagellate infusoria, there may be mentioned first the *Cercomonas intestinalis* (Fig. 516), a pear-shaped form having a spinous process at its pointed end, and a flagellum at its blunt end. It has also been found

in the intestine in catarrhal conditions, and in cholera and typhoid cases. According to Bütschli and Perroncito it is identical with *Megastoma entericum* of Grassi and *Megastoma intestinale* of Blanchard, and is in part passed off in the fæces in an encysted form (Perroncito),



FIG. 516.—*Cercomonas intestinalis*. (After Davaine.)



FIG. 517.—*Trichomonas vaginalis*. (After Kölliker.)



FIG. 518.—*Trichomonas intestinalis*. (After Zenker.)

particularly when no diarrhœa is present. It occurs also in mice, rats, cats, dogs, sheep, and rabbits (Grassi), and attaches itself firmly to the surface of the intestinal epithelium.

Kannenbergh found a *cercomonas* in the sputum in a case of lung-gangrene. In association with it there was also found *Monas lens*, a spherical infusorium with a flagellum. Strong reports a similar finding.

Of the genus *Trichomonas* an oval infusorium furnished with many flagella and a comb-like undulating fringe along its entire length, one species, *Trichomonas vaginalis*, occurs in the vagina (Fig. 517), and another, *Trichomonas intestinalis*, in the intestine (Fig. 518).

Marchand found trichomonads with four thread-shaped flagella and an undulating membrane in the urine of a man. These were probably identical with *Trichomonas vaginalis*, which also possesses four flagella. Miura reports a similar observation. Grimm saw flagellated infusoria in abscesses of the liver and lung. Lindner found ciliated infusoria in the crusts of an itching eczema of the scalp.

Lôwit, on the ground of a thorough investigation, is of the opinion that **leukæmia** is an infectious disease caused by protozoa; and describes as the cause of the same, two parasites, a *hæmamoeba leukæmiæ magna* and a *hæmamoeba leukæmiæ parva* (or *vorax*), the first of which occurs in myelogenous leukæmia, the latter in the lymphogenous variety. His opinion is supported by the histological examination of the leukæmic blood and of the organs changed by the disease, and he succeeded through the aid of special staining methods in demonstrating the presence in and upon the white blood-corpuscles of small granule-like and large amœba-like bodies, as well as sickle-, spindle-, and crescent-shaped structures, and segmented bodies in the morula stage. Flagella were also observed. Lôwit studied these appearances most thoroughly in a case of myelæmia; and was able through injections of blood or of pulp made from portions of organs, into the jugular vein of the rabbits (the injections being directed toward the brain), to produce a diseased condition, and to find in the blood of the inoculated animal the structures in question, also flagellated forms. Fürst has explained the appearances described by Lôwit as being nothing more than artefacts, and regards them as distorted, swollen, washed-out, and macerated mast-cell granules. Lôwit holds to his view in spite of this attack, and supports himself chiefly by the fact that his *hæmamoebæ* show a specific staining reaction with watery thionin and iodine, which the mast-cell granulations and similar elements do not possess; and further, that the *hæmamoebæ* are found in cells without granulation as well as those with granulation, that they show characteristic sickle-, whip-, and flagellate-forms, and form bodies even as large as 10  $\mu$  in diameter, and finally, that they do not occur in normal blood.

Recently Lôwit has reported observations on the spore-like resisting forms of *hæmamoeba leukæmiæ magna*, which he had seen in the blood-forming organs of a case of myelæmia. The earlier described flagellate-forms of the parasite seen in infected rabbits he interprets as forms standing in relation to the sexual reproduction of the *hæmamoebæ*, since the amœbæ and flagellated forms unite with each other. In man the parasite is said to reproduce chiefly by schizogony, in rabbits by sporogony (cf. reproduction of coccidia and malarial plasmodia, §§ 181, 182). To the parasites of lymphæmia,

which, according to his latest publication, he finds in the nuclei of the white blood-cells, he gives the name *Hemanueba leukæmia parva intranuclearis*. He finds these nucleoid bodies also in pseudoleukæmia, most abundantly in the spleen, to a less extent in the lymph-glands.

Hensen found infusoria with one to three flagella in the stomach-contents of a case of gastric cancer. Jacoby and Schaudinn describe two ciliated infusoria obtained from the intestinal contents of a man suffering with diarrhœa; to these Schaudinn gave the names *Balantidium monatum* and *Nyctotherus faba*.

Von Leyden and Schaudinn ("Leydenia gemmipara," Sitzber. d. K. Akad. d. Wiss., Berlin, 1896) found, in the fluid of two cases of ascites occurring in malignant disease of the abdomen, an amœba, which consisted of colorless gelatinous cells, which put out pseudopodia, and showed a hyaline entoplasm and a granular ectoplasm. They were found chiefly lying together in groups.

Protozoa belonging to the flagellates have been many times observed in the blood of animals. In 1875 Rüttig reported observations of the flagellates occurring in the blood of frogs. In 1877 Lewis described a flagellate found in the blood of an Indian rat. Kent named this *Herpetomonas Lewisii*. Evans, in 1880, found similar forms in horses, mules, dogs, camels, and cattle suffering from *surra*, a disease which is common among these animals in India, and runs a course resembling that of a pernicious anæmia. Koch and Wittich described such forms in marmots, Danilewsky (1885) in birds, fishes, and frogs. In 1894 Bruce discovered that the *tsetse disease* (*fly disease, nagana*) which occurs in Zululand and affects the cattle, horses, asses, and dogs of South Africa, is due to flagellates transmitted through the sting of the *tsetse-fly*.

All the forms of flagellates observed in the blood of different animals are generally designated as *Trypanosoma sanguinis* (Gruby,) and different species or varieties of the same are distinguished. Von Wasmielewski classes with the trypanosoma of Gruby only the blood-parasites of frogs and fishes, and would retain for the trypanosoma of mammals the name *Herpetomonas* given by Kent. The form known as *Trypanosoma sanguinis* is widely distributed among the wild rats (brown rats and gray rats), the infected rats showing no recognizable symptoms. According to von Wasmielewski the parasite is 8-30  $\mu$  long, 2-3  $\mu$  broad, possesses at its posterior end a beak-like process (Fig. 519, A), on the anterior a flagellum (d), and on its side an undulating membrane (c). By proper staining (Romanowski's stain gives the best results) there may be made visible within the cell a nucleus (a), and at the same time it may be recognized that the flagellum is continued as a border along the outer edge of the undulating membrane (e), and takes its rise at the posterior end of the animal from a rod-shaped body (b) lying upon the protoplasm-body. Rabinowitch and Kempner regard this rod-shaped body, which stains similarly to the nucleus, as a constituent of the nucleus separated in space from the vesicular chromatin-framework, and designate it the nucleolus. Likewise, Plim-

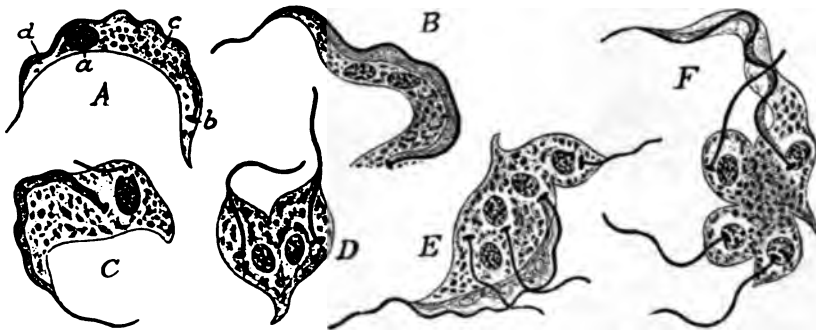


FIG. 519.—*Trypanosoma (herpetomonas) sanguinis murium* in different stages of development. (After A. von Wasmielewski.) A, Fully developed parasite with nucleus (a), rod-shaped body (b), undulating membrane (c), and flagellum (d); B, parasite with two nuclei and one rod-shaped body; C, parasite with one nucleus and two rod-shaped bodies; D, division into two parasites; E, parasite with four nuclei and four flagella; F, daughter-individuals united into a colony.  $\times 1,500$ .

mer and Bradford distinguish a macronucleus and a micronucleus; but according to von Wasmielewski the structure does not lie in the cell-plasma, but in the periplastem, from which the flagellum and undulating membrane also proceed.

As Rabinowitch and Kempner have shown, the development and multiplication of the parasite can best be followed through the intraperitoneal inoculation of healthy white and spotted rats, an increase of the parasite thereby taking place, partly in the

peritoneal cavity and partly in the blood. According to the reports of these observers, multiplication takes place partly through the longitudinal and transverse division of flagellated individuals, and partly through the segmentation of larger forms having no flagella, the division of the cell being introduced by the division of the nucleus designated by them as the chromatin framework, while new nucleoli are constricted off from the chromatin mass. According to *von Wasielewski*, the nucleus (*B*) sometimes divides first, at other times the rod-shaped flagellum-root (*C*); and the cells divide sometimes when containing two nuclei (*D*), at other times only after the formation of several nuclei and flagellum-roots (*E*, *F*), so that the flagellates during the process of constriction remain united together in a colony for some length of time.

*Plimmer* and *Bradford* claim to have seen in the case of *Trypanosoma Brucei* also conjugation processes with subsequent division; but this has not been confirmed by other investigators.

The trypanosomata of marmots, cattle, horses, birds, and fishes are similar to the trypanosoma of the rat, but according to *Rabinowitsch* and *Kempner* are separate species, and the animals named are not susceptible to the trypanosoma of the rat. The trypanosoma of rat's blood has a pointed posterior end, the *Trypanosoma Brucei* which causes the tsetse disease has a blunt conical posterior end. The trypanosoma of the surra-disease of India is probably identical with the latter.

According to experimental investigations by *Rabinowitsch* and *Kempner*, the infection of rats is brought about through the bite of diseased rats or by means of fleas; an infection through the intestine does not take place.

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§ 181. Of the **Sporozoa** occurring as parasites in man and in the mammals, the **coccidia** are to be mentioned first. In their young state they exist as non-encapsulated inhabitants of epithelial cells, particularly in those of the intestinal canal and its adnexa, the liver especially, and

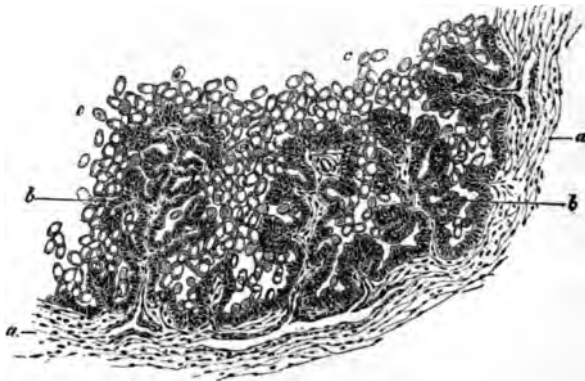


FIG. 520.—Section through the wall of a dilated bile-duct, filled with coccidia and lined with papillary proliferations. From a rabbit's liver that was studded with coccidia nodules (Müller's fluid, hæmatoxylin, eosin). a, Connective tissue; b, branching papillary proliferations covered with epithelium; c, coccidia.  $\times 23$ .

more rarely in those of the organs of excretion. Some of the mature forms surround themselves with a capsule and become changed into round or oval *permanent cysts* or *oöcysts* (Schaudinn), which leave their resting-place and usually also their host, and under certain conditions form sickle-shaped *sporozoites* through the repeated division of their cell body (*sporogony*). Through the taking-up of sporozoite-containing oöcysts into a new host there is produced an infection of the latter, in that the sporozoites are set free and seek out epithelial cells for their further development.

Besides this form of multiplication there occurs within the infected organ also a reproduction by *schizogony*—that is, there are developed from mature but non-encysted individuals, by means of segmentation, a large number of new sickle-shaped individuals, the so-called *merozoites*, which seek out epithelial cells, and develop further in the same.

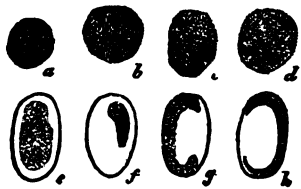


FIG. 521.—Coccidia from the biliary duct of the rabbit's liver (Fig. 520), showing different stages of development (Müller's fluid, hæmatoxylin). a, b, Small, coarsely granular young forms; c, d, large forms with darkly staining peripheral granules; e, f, g, h, oval, encapsulated forms, the protoplasm of which—partly coarsely granular and partly fine—fills up only a portion of the capsule.  $\times 400$ .

**Coccidium oviforme** (Fig. 521) is a parasite of the intestine and biliary passages, occurring especially in rabbits. Künstler and Pitres found similar coccidia in man in a pleuritic exudate. Podwyszołski claims to have observed them in the human liver.

In the liver of rabbits the invasion of coccidia leads to the formation of white nodules which may reach the size of a hazelnut, and are designated as *coccidia-nodules*. These nodules contain a soft, white, or yellowish-white mass, and consist essentially of

dilated bile-passages, the inner surface of which is more or less richly furnished with papillary growths (Fig. 520), and whose lumen contains great numbers of coccidia.

The coccidia occur in the bile-passages partly in the form of non-encapsulated protoplasmic structures, and partly in the form of encapsulated bodies. The smallest coccidia, which are regarded as the younger forms, exhibit a coarsely granular protoplasmic structure (Fig. 521, *a, b*), within which a nucleus (*a*) may occasionally be demonstrated. The larger forms exhibit on their outer surfaces regularly arranged granules (*c, d*), which stain intensely with hæmatoxylin. The encapsulated forms occur as oval, doubly contoured, clear bodies (*e, f, g, h*) within which lies a variously shaped mass exhibiting also various forms of granulation, but never entirely filling up the space within the capsule.

To the coccidia belong probably also those parasites which occur in the epidermis of man and form there peculiar growths known as **epithelioma contagiosum** (Fig. 522). In its fully developed condition the growth consists of a small nodule, about the size of a pea or larger, which is elevated above the surface of the skin, shows a small groove in its centre, and possesses a waxy lustre.

On section there may be seen a lobulated epithelial growth (Fig. 522, *d*), with a central cavity opening externally (*g*), thus forming a growth resembling a gland; and it has been many times mistaken for a hypertrophic sebaceous gland. It therefore represents an independent new-formation of epithelium due to a parasite. The parasites develop inside of the epithelial cells of the lobulated growth (*e*), but are pressed by the



FIG. 522.—*Epithelioma contagiosum*. Section through greatest diameter (Müller's fluid, hæmatoxylin). *a*, Epidermis; *b*, connective tissue; *c*, sebaceous gland; *d*, gland-like epithelial proliferations; *e*, parasites; *f*, horny cells mingled with parasites; *g*, duct filled with horny epithelium and parasites.  $\times 13$ .

growth of the adjacent epithelium toward the central cavity of the new-formation (*f*), and lie there in a meshwork of desquamated and horny epithelial cells.

The earliest stages of development of the parasites occur in the epithelial cells as small protoplasmic bodies (Fig. 523, *a, b*), which can be distinguished from the cell-protoplasm only with difficulty; occasionally they contain in their interior small, distinct granules, and are therefore more evident. Later they increase in size, and finally fill up completely the epithelial cell (*e, d, e*), pressing the nucleus to one side. At the same time the granules within the cell (*e*) increase, and grow to larger bodies, so that the parasite finally becomes divided into a greater or less number of finely granular structures (*d, e, f*) lying in a finely granular





FIG. 523.—Parasites of *Epithelioma contagiosum* in various stages of development, lying inside epithelial cells (Müller's fluid, hæmatoxylin). *a, b*, Epithelial cells, enclosing a protoplasmic body inside of which lie single large granules; *c*, epithelial cell almost completely filled with parasites; *d, e, f*, parasites completely filling the epithelial cells, and divided into numerous separate bodies lying in a granular network; the cell-nucleus has been destroyed in *f*.  $\times$  about 500.

network. The nucleus of the epithelial cell is destroyed during this time.

The epithelial cells which enclose parasites develop early a distinct membrane, which becomes more and more clearly defined, and surrounds the parasite. The parasites which are expelled from the cells form oval bodies which appear enclosed in a capsule and present a homogeneous appearance. They stain deeply with hæmatoxylin.

The contagious epitheliomata may appear in great numbers in one and the same individual, and several persons living to-

gether may be either simultaneously or successively attacked. The spread of the disease is therefore referred to a contagion.

Our knowledge of the significance of the so-called **Miescher's sacs** is still incomplete. They are tube-shaped structures which are not infrequently found in the muscles of the hog (Fig. 524, *a, b*), cattle, sheep (especially in the œsophagus), and mice. They vary in size, and lie within the muscle-fibres. In mature parasites the contents of the tubes are differentiated into single segments defined by a membrane (Fig. 524), which enclose spherical (*c*), kidney-shaped, or sickle-shaped bodies. The parasite is classed with the **Sarcosporidia**. The separate segments are designated *sporocysts* or *sporoblasts*, since within these the round or sickle-shaped *spores* (*Rainey's bodies*) arise. From the latter,

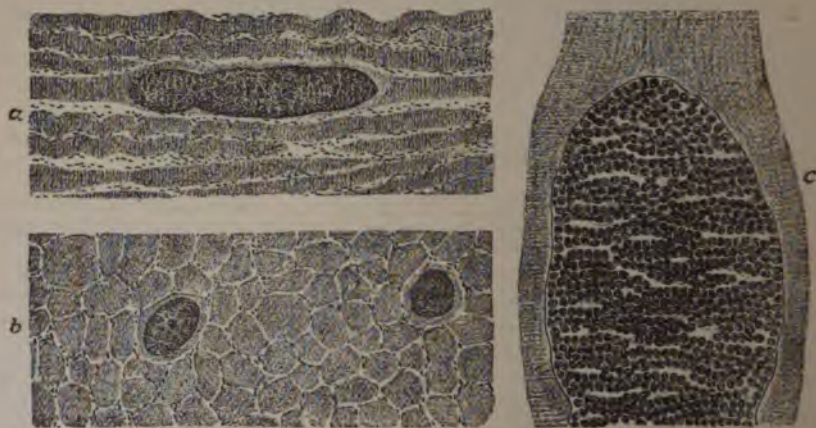


FIG. 524.—Miescher's sacs, from swine-muscle. *a, b*, Muscle cut longitudinally and transversely.  $\times$  100. *c*, Longitudinal section.  $\times$  580.

new Miescher's sacs may develop under favorable conditions (Pfeiffer). Ingestion of meat containing sarcosporidia is not dangerous for man.

As early as 1870 *Eimer* published observations of the development of coccidia, but their life-history has been accurately determined only in recent years, through the in-



vestigations of R. Pfciffer, Simond, Léger, Schaudinn, Schuberg, Siedlecki, Schneider, von Wasielenski, Labbé, and others. Lühe has recently collected in an excellent manner the results of the more recent investigations concerning the sporozoa (*Centralbl. f. Bakt.*, Bd. xxvii., xxviii.).

According to his presentation, the reproduction of coccidia occurs partly through *sporogony*, partly through *schizogony*. The first method serves for the spreading of infection and the preservation of the species, the second increases the extent of the infection within the infected host. *Sporogony* is closely connected with a previously occurring

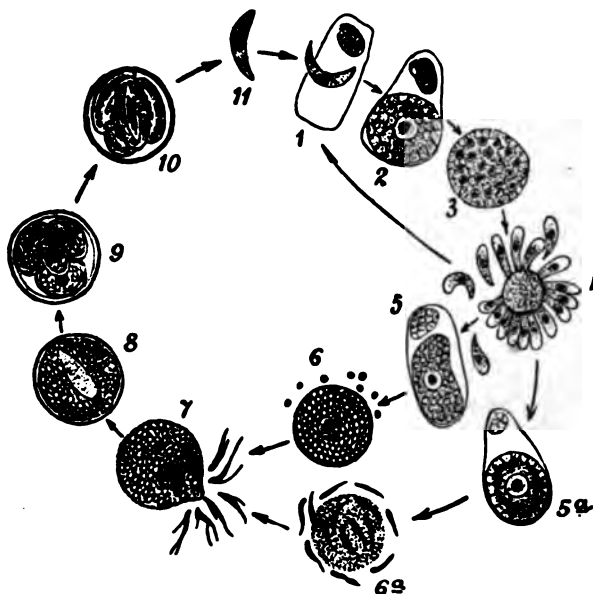


FIG. 525.—Cycle of development of *Coccidium Schubergii*. (After Schaudinn and Lühe). 1, Sporozoite (or merozoite) penetrating into an epithelial cell; 2, mononuclear schizont in an epithelial cell; 3, multinuclear schizont; 4, division of the schizont (schizogony) into numerous merozoites; 5, macrogamete (female cell) arising from a merozoite; 6, fully developed macrogamete surrounded by extruded chromatin granules; 5a, microgametocyte (male cell) arising from a merozoite; 6a, microgametocyte surrounded by loosened microgametes (spermatozoa); 7, fertilization of the macrogametes by microgametes; 8, young oöcysts; 9, oöcysts with sporoblasts; 10, oöcysts with sporocysts, each containing two sporozoites; 11, sporozoite.

*copulation* which in its course suggests the fertilization of the egg of the metazoa. An *alternation of generations* also takes place.

The development and reproduction take place in the following manner: In schizogony the sickle-shaped germ (Fig. 525, 1) arising as a *sporozoite* or *merozoite* develops within an epithelial cell into a schizont (2) in which there soon takes place a multiplication of the nucleus (3). There then results (on the second day after the over-feeding of sporocysts) a formation of merozoites (4) corresponding in number to the nuclei, and a residual body which is left behind after the segmentation.

The merozoites again seek epithelial cells, and the same development begins anew. If the affected organ, as the result of these processes, becomes overcrowded with parasites, there are then formed sexual individuals (Schaudinn). Some of the merozoites grow into large cells, the *macrogametes* (5, 6) or female cells, which when mature throw off a portion of their chromatin-substance (6), and either remain naked or surround themselves with a capsule, which is provided with a micropyle. At the same time other merozoites develop into the male sexual cells or *microgametocytes* (5a, 6a), the nuclei of which divide into many daughter-nuclei. The latter approach the surface of the cell, and, surrounded by a certain amount of protoplasm, are constricted off, (6a) and then represent the *microgametes* (corresponding to the spermatozoa of the higher animals). The *copulation* of the microgametes with the macrogametes takes place in a manner similar to that of the fertilization of the metazoan egg, in that the microgamete penetrates the encapsulated form of macrogamete through the micropyle, and the naked form through a certain point which pushes itself outward to form a prominence (7), the

conceptional protuberance. *Sporogony* follows the fertilization—that is, the oöcyst (8) is formed, in which, through the division of the nucleus and protoplasm there arise four *sporoblasts* (9), each of which later produces two sickle-shaped *sporozoites* (10).

**Sarcosporidia** have been observed in mammals (*Rosenberg* reports the finding of sarcosporidia in the heart-muscle of a European, *Kartulis* a similar finding in the abdominal muscles of a Sudanese), birds, and reptiles. Their life-history is not yet adequately known; and at the present time (*Lühe*) a classification of the sarcosporidia cannot be given.

Numerous authors hold the view that other local pathological conditions of the tissues in man than those described above may be referred to *sporozoa*, particularly *carcinoma*, *Darier's disease*, *Paget's disease*, peculiar diseases of the urinary passages, etc. It may, however, be remarked that this assumption in part is based upon error, and in part has not been absolutely proved by the investigations which have been made up to the present time.

So far as *carcinoma* is concerned, in spite of the great number of works on the subject, so numerous indeed that they can scarcely be perused (cf. § 122), no proof has yet been given that protozoa, coccidia in particular, are present within the epithelial proliferation and are to be regarded as the cause of the same. All the appearances described as occurring in carcinoma cells, even the sickle-shaped formations which have been thought to be convincing and those provided with a sort of capsule, may be otherwise interpreted, and may be explained in part as changed nuclei, in part as altered protoplasm of the cancer-cells, in part as cell excretions, and finally in part as a product of cell-fusion or of the taking up of leucocytes by the cancer cells.

The disease described by *Darier* as *psorospermose folliculaire végétante*, and referred by him to the presence of sporozoa, is very probably only an inflammatory affection of the skin characterized by a pathological cornification (*keratosis follicularis* of *von Withe*), in which little horny plugs and pegs are developed successively in the epithelium of certain parts of the body, while the cutis shows slight inflammatory changes. According to *Buzzi*, *Miethke*, *Rieck*, *Kröning*, *Petersen*, and others, the "*corps ronds*," described by *Darier* as parasites, contain kerotohyalin and eleidin, substances which are present in cornified cells but not in gregarinæ.

*Paget's disease* is an affection spreading from the nipple, beginning with an eczema-like inflammation, and leading to superficial ulceration, and finally ending in a carcinomatous infiltration of the skin. It has been referred by *Darier*, *Wickham*, *Malassez*, and others to the presence of a parasitic sporozoon in the epithelial cells; but is, however, either an eczema arising from other causes, and finally leading to cancer, or else is a primary cancer accompanied by inflammatory processes (*Ehrhardt*), in which peculiar changes take place in the epidermis, particularly swelling of the protoplasm and nuclei, with formation of vacuoles, and further proliferative changes, the peculiar appearances of which might be mistaken for parasites.

*Pisenti*, *Silcock*, *Ere*, *Bland Sutton*, and *Jackson Clarke* have pointed out the possibility that the cysts occurring in the descending urinary passages in *ureteritis cystica* are of parasitic origin. *Lubarsch* and *Aschoff* have opposed this view; *von Kuhlén* has upheld it.

According to *Kess* and *Guillebeau*, coccidia may occasion in young cattle diseases of the intestine resembling dysentery.

*Guarnieri* ("Ric. sulla patogenesi ed etiol. dell' infez. vaccinica e variolosa," *Arch. per le Sc. Med.*, xvi., 1892; "Ulter. ric. sulla etiol. dell' infez. vaccinica," Pisa, 1896), *L. Pfeiffer* ("Die Protozoen als Krankheitserreger," Jena, 1895; "Vaccine-contagium," *Zeitschr. f. Hyg.*, 23 Bd., 1896), *E. Pfeiffer* ("Züchtung des Vaccine-erregers," *Centralbl. f. Bakt.*, xviii., 1895), and others (cf. *Wasielewski*, "Zelleinschlüsse bei Vaccineimpfungen," *Centralbl. f. Bakt.*, xxi., 1897) consider the small, easily stained bodies, surrounded by a clear zone, which are found in the epithelium in the early stages of variola and vaccinia, to be protozoa. *Guarnieri* has designated the supposed parasite as *Cytoryctes vaccinae*. The parasitic nature of these bodies has not yet been demonstrated. After *Salmon* ("Parasites de la vaccine et de la variole," *Ann. de l'Inst. Pasteur*, 1897) had spoken against such a view, *Hückel* ("Die Vaccinekörperchen," *Beit. von Ziegler*, ii., Supplh., Jena, 1898) proved, through exact and carefully conducted investigations, that in vaccinia at the point of inoculation into the cornea certain portions of the epithelial cells undergo especial disease changes, and that from their protoplasm there arise those peculiar structures which have been mistaken for parasites.

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(*Darier's Disease ; Paget's Disease.*)

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§ 182. Through the investigations of Laveran, Marchiafava, Celli, Golgi, and others it has been demonstrated beyond doubt that *malaria is caused by parasites* belonging to the Protistæ, which are usually classed together under the name **Plasmodium malariae** (introduced by Marchiafava and Celli). They are also frequently designated **hæmosporidia**. The parasites are found in the blood of malarial patients in different forms, usually enclosed in cells; and, according to the observations of Golgi, Celli, Marchiafava, and others, a definite relation can be demonstrated between the number and the stage of the development of the parasite and the attacks of fever. The parasites pass through different stages of development in the interval between the attacks of fever, these stages, according to the authors mentioned, differing in *febris quartana*, *febris tertiana*, and *febris quotidiana*. At the same time the parasites of the different forms of fever exhibit certain differences in their physiological characteristics. Supported by these facts, there may therefore be distinguished in man different species of the malarial plasmodium. In its narrower sense the designation *Plasmodium malariae* is used only with reference to the parasites of quartan and vernal tertian fevers. The parasite of æstivo-autumnal or pernicious malarial fever, because of its active movements, is called *Plasmodium vivax* (Grassi and Feletti); that of quotidian fever, which also occurs in the autumn, is designated *Plasmodium præcox*.

The development and increase of the plasmodia take place within the red blood-corpuscles, in which, first of all, small, colorless amœboid bodies (Fig. 526, *a*) appear. In *quartan fever* the further development of the parasite proceeds by an enlargement of the small amœboid forms



(Fig. 526, *a, b, c, d, e*), so that the red cell becomes more and more filled up by the parasite. At the same time pigment-granules, which are

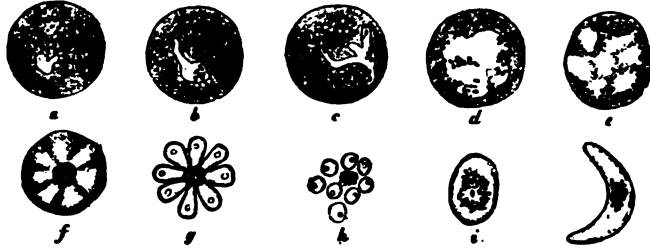


FIG. 526.—*Plasmodium malariae* of quartan fever, in different stages of development. (After Golgi.) *a*, Red blood-cell with a small non-pigmented plasmodium; *b, c, d, e*, pigmented plasmodia of varying size, inside the red blood-cells; *f*, plasmodium in beginning segmentation, with centrally placed pigment; *g*, segmented plasmodium; *h*, plasmodium divided into separate spherules; *i*, *h*, two differently-shaped, free plasmodia (sexual individuals).

formed from the substance of the red cell, appear within the bodies of the plasmodia. When the plasmodia have attained a certain size, the pigment-granules move toward the centre, while at the same time a radiating cleavage sets in, so that daisy-like figures ("rosettes") (*f, g*) are formed, which consist of a pigmented centre and non-pigmented, radiating club-shaped petals. Later the clubs become detached from the central mass of pigment and take on a circular form (*h*).

According to Golgi the development and division of the plasmodia of quartan fever require three days for their completion, and the attacks of fever coincide with the division of the plasmodia. The red cells occupied by the parasites are destroyed; the young plasmodia just formed by division penetrate again into blood-corpuscles, and the cycle of development begins anew. The pigment-granules formed by the plasmodia are taken out of the circulating blood partly free and partly enclosed in cells, and deposited in different organs, particularly in the spleen, liver, and bone-marrow.

In *febris tertiana* (*vernal tertian*) the cycle of development is completed in two days (Golgi). The plasmodia developing within the red cells (Fig. 527, *a-d*) show much livelier motion and lead much more quickly to a decolorization of the red blood-corpuscles than those of quartan fever, so that the red cells become decolorized on the first day after the fever, while the plasmodia are still small. The protoplasm of the plasmodia of tertian fever is also more delicate and less sharply contoured and the pigment-granules are smaller. In its division each plasmodium splits up into from fifteen to twenty new cells (*e*), while the parasite of quartan fever forms only from six to twelve. Finally, the red blood-cells in quartan fever are mostly crenated, while in tertian fever they

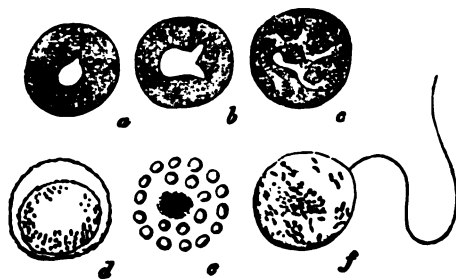


FIG. 527.—*Plasmodium malariae* of a vernal tertian, showing different stages of development. (After Golgi.) *a*, First stages of development; *b, c*, enlarged plasmodia with pseudopodia; *d*, plasmodia before sporulation, the red blood-cell decolorized; *e*, sporulation; *f*, free parasite with flagellum (microgametocyte).

retain their shape. According to Celli and Marchiafava, sporulation not infrequently occurs prematurely, from five to ten spores arising within a red corpuscle.

The parasite of *æstivo-autumnal* or *pernicious malaria* differs from the hæmosporidia of the vernal fevers, particularly in the fact that it is much smaller (Fig. 528, *a, b, c, d*) and executes lively movements within the red cells. It completes its life-cycle in forty-eight hours. During the stage of multiplication the parasite collects in the internal organs, so that the division-figures (*d*) must be sought in the spleen, liver, bone-marrow, and brain (where they are present in great numbers). Some of the infected red cells become crenated and prickly, and of a brassy color (Marchiafava, Celli); they die prematurely, and blood-cells, which contain no parasites, are also destroyed. The attacks of fever can in the case of autumnal tertian fever become so prolonged that they pass into one another, and the condition thereby assumes the character of a *sub-continuous* or *continuous fever*.

The parasite of the true *æstivo-autumnal quotidian fever* is still smaller than that of the autumnal tertian, completes its development in twenty-four hours, and produces but little pigment. According to Marchiafava and Celli there also occurs a quotidian parasite very similar to the latter, but producing no pigment at all.

According to Celli, Marchiafava, and Bignami, *nuclear bodies* may be demonstrated, during certain stages of development, in the protoplasm of all the endoglobular forms of malarial hæmatozoa. According to Ziemann, in *sporulation* there first occurs a *division of the chromatin into small clumps*, and then later the division of the cell-body, so that every clump of chromatin is surrounded by a zone of protoplasm.

Besides the forms of development already described which lead to an intracellular increase of the plasmodia through *schizogony*, there occur particularly extraglobular, in part also endoglobular, round and oval, sickle- or crescent-shaped structures (Figs. 526, *i, k*; 528, *e, f*), as well as round bodies with flagella (Figs. 527, *f*; 528, *g*), which also contain a nucleus and pigment. The crescent forms occur particularly in the

pernicious (*æstivo-autumnal tertian*) fever (Fig. 528, *e, f*). Celli regards them as a diagnostic feature of this form of fever; and Ziemann also holds that typical crescents are not formed in the other varieties of malaria.

The last-named forms Laveran had already described as structures belonging to the cycle of development of the plasmodia, while Golgi, Canalis, Celli, Marchiafava, Bignami, Bastianelli, Ziemann, and others regarded them as sterile vegetation-forms.

First through the investigations of Manson, Bignami, Ross, and MacCallum, to which were later added those of Grassi, Bastianelli, Bignami, Celli, Laveran, Koch, Schaudinn, and others, it was shown that the *crescents*, the *oval bodies*, the *spherical bodies*, or *spheres*, as well as the

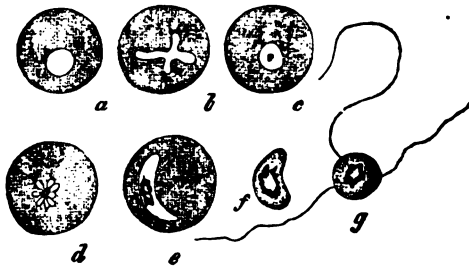


FIG. 528.—*Plasmodium vivax* of autumnal tertian, showing different stages of development. (After Celli and Sanfelice.) *a*, First stages of development; *b*, plasmodia with pseudopodia; *c*, round plasmodium with pigment, before segmentation; *d*, sporulation; *e*, intraglobular crescent; *f, g*, free plasmodia (sexual cells).

flagellated bodies known as *polymitus*, are intended for the reproduction of the parasites by copulation. The flagella-producing hyaline spheres arising from the crescents are *male sexual individuals* or *microgametocytes*, and the flagella developing from them, in whose formation the chro-

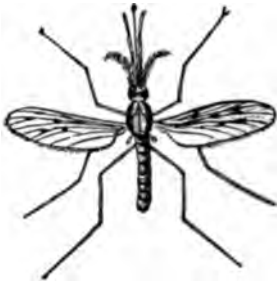


FIG. 529.

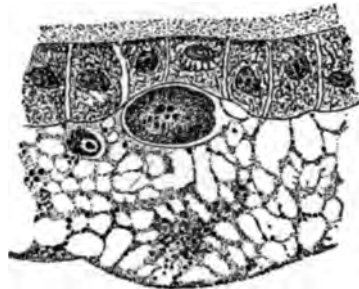


FIG. 530.

FIG. 529.—*Anopheles claviger*. (After Meigen, *loc. cit.*)  $\times 4$ . To the right a wing at higher magnification.

FIG. 530.—Oökinete of human pernicious malaria (æstivo-autumnal tertian) in the intestinal wall of a mosquito. (After Grassl.)

matin of the cell takes an essential part (Sacharoff), have the significance of *seminal cells*, *spermatozoa*, or *microgametes*; while the non-flagellated spheres arising from the granular crescents have the significance of *female sexual cells* or *macrogametes*. The crescents leading to the formation of the sexual cells appear only after the infection has lasted for several days. In the chronic cachexia following malaria the forms leading to schizogony are absent, and the crescents alone are present.

The *copulation of the malarial parasites* of man takes place normally in the *stomach of the mosquito*, in different *species of Anopheles* (Fig. 529), which take up the malarial parasites during the sucking of blood from malarial patients.

The *copula* arising from the union of the macrogamete and microgamete is designated *oökinete* (Schaudinn), a long, motile structure (described earlier as *vermiculus* by Danielewsky) which penetrates into the stomach-wall of the mosquito (Fig. 530), where through the formation of a capsule it becomes the *oöcyst*. The latter then enlarges, and forms numerous daughter-nuclei, and then *sporoblasts*, which break up into the *sporozoites* (Fig. 531) and the residual body.

The sporozoites, which are formed in enormous numbers, pass into the body-cavity after the rupture of the oöcyst, and collect principally in the salivary glands, and through the bite of the infected mosquito are again transmitted to man, in whose blood they multiply within the red blood-cells through schizogony.

The *pathogenic significance of the malarial plasmodia* rests in the first place upon the destruction of red blood-cells. In the pernicious form this may be so extensive that hæmoglobinuria may take place. The melanotic pigment formed in the parasite is a product of the vital activity of the parasites. In addition, as the result of the destruction of hæmoglobin, there occur deposits of hæmosiderin in the bone-marrow, spleen, liver, and occasionally also in the kidneys. The massing of the parasites of pernicious malaria in the cerebral capillaries may cause circulatory disturbances with the occurrence of numerous hæmorrhages,

and consequent severe cerebral symptoms (perniciosa comatosa, soporosa, apoplectica, meningitica).

As the result of the retention of pigment-containing malarial parasites and the deposit of the products of blood-destruction, there occurs a marked swelling of the spleen associated with hyperæmia, followed in part by tissue-degenerations and in part by tissue-proliferations.



FIG. 531.—Oöcyst of human pernicious malaria (æstivo-autumnal tertian), filled with sporozoites. (After Grassi.)

After a long duration of the process the spleen may become markedly enlarged, pigmented, and greatly changed in structure. Likewise, in the liver there may be found in part degenerations and pigmentations, and in part also indurative proliferations.

Certain varieties of the plasmodium correspond to the individual types of fever, as given above, but it must be noted that the fever-forms known as quotidian, subcontinuous, and continuous ("comitata"), may also arise through the presence in the blood of different generations of the plasmodia of tertian

or quartan fevers, so that daily a portion of the parasites comes to sporulation. In this way there arise quotidian forms of fever, which must be regarded as a double tertian infection (quotidiana triquartanaria).

It is not yet determined whether the malarial parasites produce toxins; such production has been many times assumed, but never demonstrated. The recurrences of malarial fever weeks and months after the original infection likewise cannot be explained. The assumption of Golgi that the crescents, which may be found in the circulating blood during the interval, aid in the production of the recurrence, is opposed by others (Celli). According to Plehn basophile granules are found in the red cells as long as the infection lasts; when it ceases they disappear.

The malaria occurring in northern countries corresponds in general to the vernal forms of Italy, while the æstivo-autumnal form is found in the tropics.

**Hæmosporidia**—that is, sporozoa which live at the cost of the red blood-cells, and thereby produce diseases which are to be classed with malaria—occur very frequently in animals. Those of birds are best known (Danilevsky, MacCallum, Ross, Grassi, Dionisi, Celli), and the life-cycles of the hæmosporidia of the pigeon, owl, and skylark have been determined. Lubbé distinguishes two genera in birds, *Halteridium* and *Proteosoma* (*Hæmoproteus* of Kruse); as to the number of undifferentiated species, nothing can be said at the present time. Celli obtained from the birds mentioned three well-defined species.

Of the **Mammalia**, cattle in particular suffer in different countries (Southern States of North America, Italy, South Africa, Roumania) from a malaria characterized by high fever and hæmoglobinuria. In the malaria of cattle known as *Texas-fever*, Smith and Kilbourne found in the red blood-cells a small, often pear-shaped, and paired parasite (*Piroplasma bigeminum*), whose pathogenic significance they determined through the inoculation of healthy cattle with blood containing the parasites. They showed further that the natural infection takes place through parasitic ticks living upon the cattle, the infection being transmitted, not by the same tick which takes up the infected blood, but only through the generation descending from the same. This mode of infection was confirmed by Koch in the hæmoglobinuria of cattle occurring in German East Africa and by Grassi in that occurring in cattle in Italy. The mode of development of the *piroplasma* in the body of the tick is still unknown; and it therefore cannot



be decided whether the parasite should be classed with the known malaria parasites. Against a near relationship with the latter speaks the fact (Lühe) that it increases within the red blood-cells by a repeated simple division. According to Koller, there occurs in South Africa, besides Texas-fever, another malarial disease of cattle (*Febris malaria-formis*), which is caused by a similar endoglobular parasite.

According to Bonome and Celli hæmosporidia also cause malaria in sheep and lambs, according to Piana and Galli-Valerio also in dogs, according to Koch and Kossel also in apes, and according to Dionisi in bats; but the life-history of all these parasites is unknown.

Danilewsky and Celli have described hæmosporidia in the frog, and the latter observer determined also the development of the parasite in the blood.

Whether the malarial parasites of man can be transmitted to animals, or whether the malaria of animals can lead to an infection of man through the medium of mosquitos, is not decided with certainty, but appears improbable. The plasmodia of the bat most closely resemble those of man, yet attempts at inoculation made by Dionisi gave no positive results. It may therefore be assumed that malaria would die out in a given region, either when all susceptible anopheles were killed, or all infected human individuals healed or protected from mosquito bites.

The malarial plasmodia are stained best by the Romanowski stain, which differentiates the nucleus.

The view that mosquitos were concerned in the distribution of malaria is very old, and has obtained in Italy since Roman times. Koch found it held as a popular belief also among negroes. In recent times Manson (1896) and Bignami (1896) were the first to turn their attention to the problem and to give hypotheses concerning the rôle played by mosquitos in the spread of malaria. Bignami carried out experiments along this line, but came to no positive result. Ross was the first (1897-98) to determine the cycle of development of the malarial plasmodium of birds (usually known as proteosoma). According to his investigations, the parasites taken up with the blood of the infected bird into the intestinal canal of mosquitos penetrate into the intestinal wall and there change into cysts in which innumerable rod-shaped germs develop. Becoming free, these germs gain entrance into the salivary glands of the mosquitos, and thence into the organism of the bird during the act of blood-sucking. Ross found the parasites in the blood of the infected bird in from five to nine days after the infection.

About the same time, Grassi found through painstaking observations that the distribution of malaria in man corresponded to the distribution of *Anopheles claviger* (Fabricius) (Fig. 529), and not to that of the common mosquito (*Culex pipiens*). Basing his experiments upon this observation, Bignami succeeded in producing malaria in healthy men by means of the bite of anopheles. Later Grassi, in coöperation with Bastianelli and Bignami, succeeded in determining the life cycle of the malarial parasite. It was then shown that several species of anopheles native in Italy (*Anopheles claviger* [Fabricius] or *Anopheles maculipennis* [Meigen], *Anopheles superpictus*, *pseudopictus*, *bifurcatus*) spread the malaria occurring in man, while *Culex pipiens* is the host of the parasites of bird-malaria.

The cycle of development of the malaria plasmodium is as follows: Within the

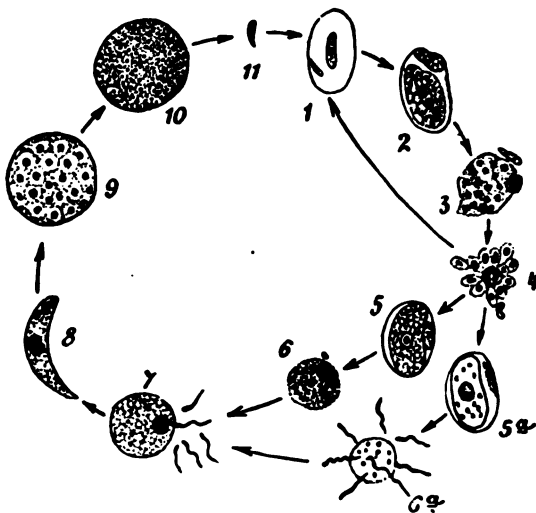


FIG. 532.—Cycle of development of *Proteosoma*. (After Schaudinn and Lühe.) 1, Sporozoite (or merozoite) within a red blood corpuscle; 2, schizont; 3, schizont with numerous nuclei; 4, schizogony, formation of merozoites; 5, macrogamete (female cell) arising from a merozoite; 6, fully developed macrogamete after extrusion of the karyosome; 6a, microgametocyte (male cell) arising from a merozoite; 6a, microgametocyte surrounded by loosened microgametes (spermatozoa); 7, fertilization of the macrogamete; 8, oökinete; 9, oöcysts with sporoblasts; 10, oöcysts with sporozoites; 11, free sporozoite.

blood (of man as well as of birds) the multiplication takes place first by *schizogony*. The young form of the plasmodia, represented by a small, unpigmented body, grows within the red cells (Fig. 532, 1) into a larger body (2), in whose central portion pigment-granules collect. This cell-body known as *schizont* shows in preparation for schizogony an increase of nuclei (3), and then divides into a number (varying with the species) of *spores* or *merozoites* (4) with the abandonment of a pigmented residual body. The merozoites then seek a red blood-cell (1), and the cycle is again begun.

In *sporogony* the merozoites develop into sexual individuals, macrogametes (5) and microgametocytes (5a). When taken up into the stomach by blood-sucking mosquitos, the sexual individuals become ripe for fertilization, the macrogamete by throwing off the karyosome (6), the microgametocyte through the formation of microgametes (6a). Copulation then follows (7). From the copula arises the motile ookinete (8), which in the wall of the mosquito's intestine becomes the oöcyst, in which through the division of the nucleus the sporoblasts (9) are formed, which in turn break up into a large number of sporozoites (10), which (11), becoming free, collect chiefly in the salivary glands, and are thence transferred by the bite of the mosquito to a new host, in whose blood they increase through schizogony (1-4).

The larvæ of anopheles live chiefly in slowly flowing water. The eggs of *Anopheles claviger* require about thirty days at 20°-25° C. for the development of the insects, and these in turn lay eggs when twenty days old. The pupæ are resistant to drying, to cold, and to contamination of the water. The mosquitos fly during the evening and night, but do not rise very high above the level of the earth, and do not go very far away from the place of development. According to Grassi, Bignami, and Bastianelli, the restivo-autumnal parasites will not develop in anopheles at a temperature of 14°-15° C., and grow only slowly at 20°-29° C.; at 30° C. they complete their entire development up to the formation of sporozoites in about seven days.

The literature concerning malarial parasites is extremely rich. The results of the latest investigations are given in the publications of Mannaberg, Nuttall, Celli, Marchiafava, Bignami, and Lühe (see below). The last-named treats particularly of the question of the position of the malarial parasites in the zoological system and their relation to the other sporozoa, in particular to the coccidia.

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## II. Vermes (Worms).

### A. PLATYHELMINTHES (FLAT-WORMS).

#### 1. Trematoda, Sucking Worms.

§ 183. The **Trematodes** or *sucking-worms* are flat-worms of tongue or leaf shape. They possess a clinging apparatus in the form of ventral sucking-cups of varying number, and are sometimes furnished with hooks or clasp-like horny projections. The intestinal canal is without an anus, and is usually forked. The development takes place either by the direct growth to maturity of the embryos (*miracidium*) hatching from the eggs, or by the method of alternate generation through the *formation of germs within the host*. The miracidium, or ciliated embryo, penetrates into a snail or mussel, and there grows into a *germ-sac* (*sporocyst*), within which there later develops, either directly or after the formation of an intermediate generation of germ-sacs (*rediae*), a swarming generation of *cercariae*, which are provided with rudder-like tails. These lose their tails and penetrate into a new host (mollusks, arthropods, fish, amphibia), become encapsulated, and attain sexual maturity as soon as they reach the final host. The germ-sacs which produce cercariae are designated primary germ-sacs ("*Ammen*"); if they first form rediae and then cercariae, they are called secondary germ-sacs ("*Grossammen*").

**Distoma hepaticum**, or liver-fluke, is a leaf-shaped sucking-worm about 28 mm. long and 12 mm. broad (Fig. 533). The cephalic end projects like a beak, and bears a small sucking-cup, in which the mouth is placed. Close behind this, on the ventral surface, is a second sucking-cup, and between the two lies the sexual orifice.

The uterus consists of a convoluted, globular sac behind the posterior sucking-cup. On each side of the hinder part of the body lie the yolk-sacs, and between the same are found the testicular canals, which branch many times. The forked intestinal tract (not visible in Fig. 533) is repeatedly branched.

The eggs (Fig. 534) are oval, 0.13 mm. long and 0.08 mm. broad. In water there develops an embryo, the *miracidium* (Fig. 535, A), with



cellular germ-balls (*a*); with the aid of its ciliated covering the embryo swims about, and seeks out a new host from the family of mollusks (*Limnæus minutus*). On penetration into the snail the cutaneous layer is thrown off, and the *miracidium*, which possesses an intestine, an excretion-organ and a brain-ganglion, becomes changed into a *sporocyst* (*B*), in which the intestine and nervous system atrophy, while the cellular germ-balls develop further (*B, a*) and form a *second generation of germ-sacs*, the *rediae* (*B, b*).

The *rediae* (*C*), which possess an intestine (*C, a*), produce then within the same host the *cercariæ* (*D*) from cells which are loosened from their germ-matrix (*C, b*); these abandon the host and with the aid of a rudder-like tail swim about in the water. With the loss of their tails they become encysted upon almost any foreign body, and then reach their final host (usually through the food), in which they attain sexual maturity. The sexually mature animal inhabits the biliary passages; more rarely it is found in the intestine or inferior vena cava. The liver-fluke is rare in man, but common in the ruminants. The results of its invasion, especially when it is present in great numbers, are obstructions and ulcerative strictures of the bile-passages, formation of biliary concretions, inflammation of the tis-



FIG. 533.

FIG. 533.—*Distoma hepaticum* with male and female sexual apparatus. (After Leuckart.)  $\times 3.2$ .



FIG. 534.

FIG. 534.—Eggs of *Distoma hepaticum*. (After Leuckart.)  $\times 200$ .

sues in the neighborhood of the bile-ducts, and hyperplasia of the connective tissue of the liver with atrophy of the glandular tissue.

***Distoma lanceolatum*** is only 8-9 mm. long and 2-2.5 mm. broad, is lanceolate-shaped, and the cephalic portion is not especially marked off from the body (Fig. 536).

The skin of the body is smooth. Two irregularly lobed testicles (*h*) lie close behind the ventral sucking-cup, in front of the ovary (*o*) and the uterus (*u*), the coils of which shine through the transparent body. The anterior coils are black with the ripe eggs, the others are rusty red. The yellowish-white yolk-sacs (*d*) lie in the middle of the lateral margin.

The oval eggs are 0.04 mm. long, and while still in the uterus contain an embryo which escapes only after several weeks following the casting-off of the eggs. Its metamorphoses are unknown.

*Distoma lanceolatum* likewise inhabits the bile-passages, but is very rare in man. It is of more frequent occurrence in sheep and cattle.

When present only in small numbers, it causes no marked changes; but the presence of large numbers may excite inflammation and proliferation of the periportal connective tissue.

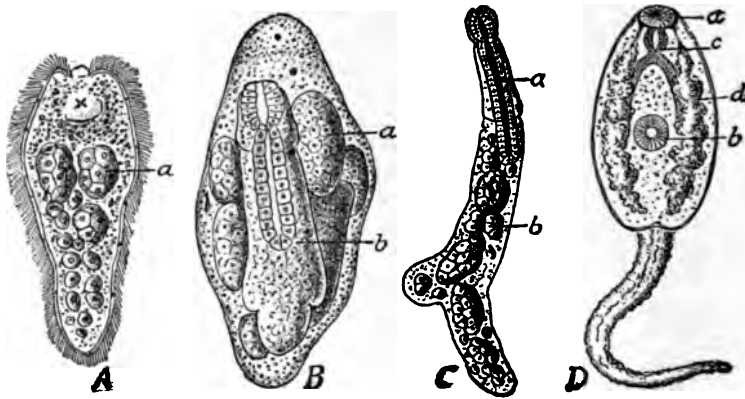


FIG. 535.—Development of the liver-fluke. (After Leuckart.) A, Miracidium with germ-balls (a); B, sporocyst with germ-balls (a) and rediae (b); C, redia, with intestine (a) and germ-balls (b); D, cercaria with mouth (a), abdominal sucking-cup (b), intestine (c), and glands (d).

*Distoma spathulatum* (Fig. 537) is a sucking-worm occurring in man in Japan and China. It is 10–14 mm. long and 2.5–4 mm. broad.

The eggs are 0.027–0.03 mm. long and 0.015–0.018 mm. broad. The parasite inhabits usually the bile passages and the gall-bladder, but may also gain access to the pancreatic duct (Katsurada), and pass out into the intestine. When occurring in great numbers (Katsurada counted 4,361 in one case) it causes an obstruction to the outflow of the bile, and often excites a more or less severe inflammation and proliferation of connective tissue.

The parasite is found also in cats and dogs (Katsurada).

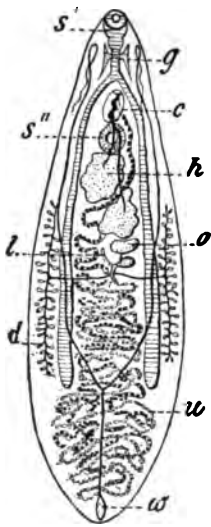


FIG. 536.—*Distoma lancolatum*. (After Hertwig.) s<sup>1</sup>, Anterior sucking-cup, and entrance into the forked intestine; s<sup>2</sup>, posterior sucking-cup; h, testicles with vasa deferentia; c, cirrus; u, uterus; o, ovary; l, duct of Laurer and shell-gland; d, yolk-stalks and duct leading to the shell-gland; w, water-vessel; g, ganglion.  $\times 8$ .

*Distoma Westermanni* (Kerbert), or *Distoma pulmonale* (Baelz) also occurs in Japan, China, and Corea. The worm is 7.5–10 mm. long, 5–7.5 mm. broad, egg-shaped, with slightly flattened ventral surface. The oval eggs are 0.09 mm. long and 0.056 mm. broad. The internal organization (Fig. 538) resembles that of the other trematodes. It occurs in man as well as in cats and dogs (Katsurada). It is found most frequently in the lungs, but occurs also in other organs: the pleura, brain, liver, intestinal wall, peritoneum, orbital cavity, eyelid, scrotum, etc. In each case it occupies small cavities surrounded by newly formed connective tissue, and occurs occasionally in pairs. In the lung it may be found also in the bronchi, the walls of which show inflammatory changes (Katsurada). Its presence in the lung may give rise to hæmoptoë and cause death. The number of lung-

flukes may run from twenty to thirty or even higher. Healing of the disease is possible after death of the parasite.

**Distoma felineum** (Rivolta) or *Distoma sibiricum* (Winogradow) is a flat, almost transparent sucking-worm, of from 8–18 mm. in length and 1.5–2.5 mm. broad, which is present in the bile-passages of the cat and dog, and in a few countries (Siberia) has been observed in man. According to Winogradow it is the most common parasite in Tomsk. Askanazy recently observed a case in Königsberg.

The inflammatory proliferations which the different forms of distoma cause in the liver of man, as well as in animals, may be followed by the development of carcinoma.

In **Distoma hæmatobium** or *Bilharzia hæmatobia* (Fig. 539) the two sexes are separate. The mouth and ventral cups lie very close together on the tapering anterior extremity. In both sexes the sexual openings lie close behind the ventral sucking-cup. The male is 12–14 mm. long.



FIG. 537.

FIG. 537.—*Distoma spathulatum*. (After Katsurada.) *a*, Mouth sucking-cup; *b*, intestine; *c*, uterus; *d*, testes; *e*, yolk-stalks; *f*, sperin-pouch; *g*, ovary.  $\times 6$ .



FIG. 538.

FIG. 538.—*Distoma Westermanni*, flattened by pressure, in the ventral position. (After Katsurada.) *a*, *a1*, Mouth and abdominal sucking-cup respectively; *b*, intestinal loops; *c*, testes; *d*, ovary; *e*, yolk-stalks; *f*, shell-gland; *g*, uterus; *h*, excretory vessel.  $\times 7.2$ .

The body is flat, but in its posterior portion is rolled together to form a tube (Fig. 539) which serves for the reception of the female.

The female is 16–19 mm. long and nearly cylindrical. The eggs are an elongated oval (Fig. 540), 0.12 mm. long, and possess a terminal or a lateral spine. According to observations by Sonsino, no alternation of generations occurs in the development of *Distoma hæmatobium*. The



part of intermediate host is taken by small crustacea, into which the ciliated embryo, swimming around in water, bores its way to become encapsulated in the tissues of its host. It is therefore probable that the infection may be transmitted through the drinking of water infected with the larvæ.

The worms are found in the trunk and branches of the portal vein, in the splenic vein, mesenteric veins, as well as in the vessels of the rectum and bladder; and may pass through the inferior mesenteric vein into the hæmorrhoidal and vesical veins, the veins of the ureter and prostate, and by chance into the inferior vena cava, and thence into the lungs. Their eggs are distributed therefore especially throughout the mucosa and submucosa of the ureters, bladder, and rectum, and occasionally also in the liver, lungs, kidneys, and prostate. While still within the urinary passages the cylindrical embryos (miracidia) covered with fine cilia may



FIG. 539.



FIG. 540.

FIG. 539.—*Distoma hæmatobium*. (After Leuckart.) Male and female, the latter lying in the *canalis gynæcophorus* of the former.  $\times 10$ .

FIG. 540.—Eggs of *Distoma hæmatobium*. (After Leuckart.) a, Egg with terminal spine; b, egg with lateral spine.  $\times 150$ .

develop. Kartulis found them also in the skin of the leg and foot, and is of the opinion that the infection may take place not only through the intestine, but also through the skin.

The deposit of eggs causes severe inflammations which lead in part to tissue-destruction and in part to proliferations of the tissue, which appear in the mucous membranes as papillary and polypoid formations. In the bladder it may lead to incrustations and formation of concretions, and also to the development of fistulous tracts. In the liver the process leads to a connective-tissue induration. Following the inflammatory process, a development of carcinoma may take place in the bladder, seminal vesicles, prostate, and in the skin (Kartulis).

The parasite is found along the entire eastern coast of Africa, and also in Zanzibar, Tunis, Lake Nyassa, in Beyrout, and in Sicily. It is most common in Egypt, where about twenty-five per cent. of the native population suffer from the disease.

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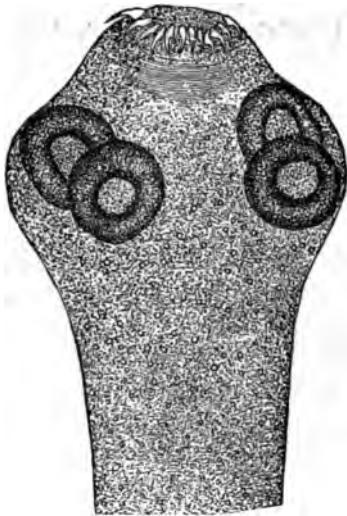
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## 2. Cestoda (Tapeworms).

§ 184. The **tapeworms** are *flat-worms devoid of mouth or intestine*, which increase after the method of alternate generation through the germination of a pear-shaped primary head or scolex, and remain united to the latter for a long time as a (usually) long, band-shaped colony. The single segments of this colony, the sexually active individuals, or **proglottides**, increase in size the more widely they become separated from their place of origin by the formation of new members, but outside of this are devoid of any outward distinguishing peculiarity. The pear-shaped **head** or **scolex**, on the other hand, is provided with from two to four suckers, and usually also with curved claw-like hooks. With the aid of these clinging organs the tapeworms fasten themselves to the intestinal wall of their host, which appears to be invariably one of the vertebrate animals. The scolices develop from a round embryo having four to six hooks, and are found as the so-called "measles" in the most diverse organs, chiefly the parenchymatous ones, from which they later pass by a passive migration into the intestine of their future host.

The *tapeworms occurring as parasites in man* belong to different families - the *Tæniadæ* and the *Bothriocephalidæ*. The first occur in man either as "measles" or as tapeworms, the latter only as tapeworms.

§ 185. *Tænia solium* in its fully developed condition possesses a length of 2-3 metres. The head (Fig. 541) is of the size of a small pin-head, is spherical in form, with rather prominent sucking-cups. The crown of the head is not infrequently pigmented and bears a fairly large rostellum with about twenty-six plump, close hooklets having short root-processes. Following the head there is a thread-like neck of about an inch in length. At a certain distance from the head segmentation begins, the first segments being very short, but their length increases with their distance from the head (Fig. 542); they become quadratic and finally longer than broad. The mature segments appear about 130 cm. behind the



A.

FIG. 541.



FIG. 542.



FIG. 543.

FIG. 541.—Head of *Tænia solium* with protruding rostellum (carmine, balsam).  $\times 50$ .

FIG. 542.—Half-developed and fully matured segments. Natural size. (After Leuckart.)

FIG. 543.—Two proglottides with uterus. (After Leuckart.)  $\times 2$ .

head, although the sexual organs are fully developed in earlier segments. The ripe segments (Fig. 543) are, when stretched out, 9-10 mm. long, and 6-7 mm. broad, and have rounded corners. The sexual opening is situated laterally just behind the middle of the segment. The uterus, which is filled with eggs, possesses seven to ten lateral branches which are separated from each other by a wide interval, and break up into a varying number of boughs branching like a tree.

The parenchyma of the body of mature as well as of immature *proglottides*, or tapeworm segments (Fig. 544), is divided into two chief layers, the central one being designated the middle layer, the peripheral one as the cortical layer. The middle layer contains the sexual apparatus (Fig. 544, *c, d, e, f, g, h, i, k, l, m, n*), as well as the water vascular system (*a*), an excretory apparatus which traverses the whole tapeworm from the head to the last segment in the form of two canals lying in the lateral border of the middle layer. The canals are connected with each other at the posterior end of each segment (*a'*) and also send out numerous fine, subdividing branches into the body-parenchyma.

The sexual apparatus consists of male and female sexual organs, which lie close together. A number of small, clear vesicles serve as testicles (c), they lie chiefly in the anterior portion of the middle layer. The vas deferens (e), which is connected with the testicles by the seminal ducts (d), empties into a grooved papilla situated on the lateral border (h). The coiled end (f, g) lies in a muscular bag and may be protruded through the sexual opening (cirrus). The female sexual opening lies close behind the male orifice in the same sexual cloaca. The vagina (i) leads thence to the posterior border of the segment. Before this is reached it widens into the seminal vesicle, and behind this into the fructifying canal and the so-called "globular body." The germ-preparing organs, which must be sought in the immature segments, consist of a double ovary (k) and a single albumin-gland (l); these are sac-like or tubular organs lying in the posterior portion of the segment and communicating with the globular body. The latter is joined to the anteriorly located uterus (n), which at the time of sexual maturity forms a straight canal. When the eggs enter the uterus from the globular body, in which they pass their first stage of development, the above-mentioned lateral branches sprout out and become filled with eggs. During this process the remaining sexual organs disappear.

The cortical layer of the proglottides is essentially muscular in nature, but in addition contains a larger or smaller number of so-called calcareous bodies, which are not entirely wanting in the middle layer as well. The musculature consists of smooth fibres, which form special groups in the suckers of the head. The surface of the tapeworm is covered with a clear cuticle, which forms the hooks on the heads.

The eggs in the ovary are thin-skinned, pale and yellow, nearly globular cells. In the uterus they change into yellow balls having a thick, more or less opaque shell, covered with closely set spicules (Fig. 545, a). The latter is often surrounded by a second layer, an albuminous envelope (b) limited by a membrane; and in it there are embedded granules (primitive vitelline membrane). The diameter of the eggs, not including the vitelline membrane, is about 0.03 mm.

The thick-shelled spheres are not undeveloped eggs, but contain an embryo with six hooklets. An intra-uterine development of the embryo therefore takes place, the ripe segments are pregnant animals.

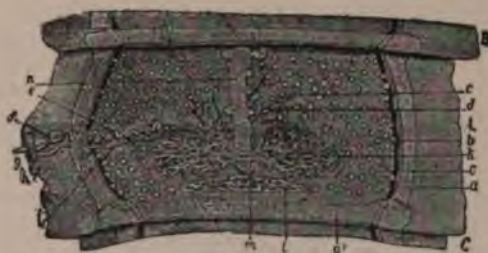


FIG. 544.—Segment of *Tænia solium* with fully developed sexual apparatus. (After Sommer.) A, Surface view of segment; B, border of next anterior segment; C, that of next posterior segment; a, longitudinal excretory trunk; a', transverse anastomosis; b, longitudinal plasma-vessel; c, testicular vesicles; d, seminal ducts; e, vas deferens; f, cirrus-bag with cirrus; g, porus genitalis; h, border papilla; i, vagina; k, ovarium; l, albumin-gland; m, egg-gland, and oviduct in front of same; n, uterus.  $\times 27$ .



FIG. 545.

FIG. 546.

FIG. 545.—Eggs of *Tænia solium*. b, With primitive vitelline membrane; a, without primitive vitelline membrane. (After Leuckart.)  $\times 300$ .

FIG. 546.—*Cysticercus cellulosus*, with fully developed head in situ. (After Leuckart.)  $\times 4$ .



The further development of the embryos enclosed in the brownish shells takes place ordinarily in a new host. Should they gain access to the stomach of a hog, the egg-shell is dissolved, and the embryos, thus set free, penetrate into the stomach

or intestinal wall. Thence they pass either by the blood-stream or by an active migration through the tissues into this or that organ. Having reached a resting-place, the embryos undergo various metamorphoses and become changed inside of two or three months into a cyst filled with serum (Fig. 546), the inner wall of which shoots forth into a bud from which there develops a new tapeworm head, a scolex, as well as a sac enclosing the same, a *receptaculum scolice*.

The cyst containing a tapeworm head is known as a "measle" or *cysticercus cellulosæ*. The scolices, when fully developed, possess a circle of hooklets, suckers, a water-vascular system and numerous calcareous bodies in their body-parenchyma. If they gain access to the human stomach, the cyst is dissolved, and there develops, through the formation of segments from the scolex (*Amme*), a new chain of proglottides, a new *Tænia solium*.

The *Tænia solium* inhabits the small intestine of man, and is acquired by the eating of uncooked



FIG. 547.—Cysticerci of the *Tænia solium*, in the epicardium and myocardium of a hog.

pork, since the "measles" belonging to this parasite occur almost solely in the hog and in man. By means of its sucking-cups and its circlet of hooks it clings firmly to the mucosa of the intestine; the remaining portions float freely in the intestine. Usually but a single parasite is present in the intestine, although the presence of several at the same time is not rare. Occasionally as many as thirty or forty have been observed in one individual. They excite irritation of the intestinal mucosa, colic, and reflex disturbances of the central nervous system.

The "measles" occur in the tissues of the hog, sometimes singly, sometimes in great numbers (Fig. 547), and individual organs, as the heart, for example, may be closely studded with them.

In man, *cysticerci* occur in the most varied tissues—the muscles, brain, eyes, skin, etc. In the meninges and in the brain the measles may appear in the form of mulberry or grape-like collection of cysts, known as *cysticercus racemosus* (Zenker). The cysts are for the greater part sterile, though some of them may contain a scolex.

The importance of the measles depends upon its location, but is in gen-



eral slight. Its presence in the brain often causes severe disturbances, but in other cases all signs of disease may be lacking. Locally it excites a slight inflammation, which leads to a thickening of the connective tissue in its immediate neighborhood. The cyst may retain its vitality for years. After the death of the scolex the cyst contracts and there is deposited within it a chalky mass. The hooklets are preserved in this mass for a very long time. Infection with the "measles" follows the introduction of eggs or proglottides into the stomach of man.

*Tænia mediocanellata* or *saginata* surpasses the *Tænia solium* not only in length, as it measures 4-7 metres and more, but also in its breadth and thickness, as well as in the size of the proglottides (Fig. 548).

The head is devoid of rostellum and circle of hooklets (Fig. 549), has a flat crown and four large, powerful suckers, which are usually surrounded by a black border of pigment.

The eggs resemble those of *Tænia solium*. The fully developed pregnant uterus (Fig. 550) has a large number of lateral branches which run close to each other, and instead of branching dendritically divide dichotomously. The sexual opening lies back of the middle of the lateral border. The segments discharged spontaneously are for the greater part empty of eggs.



FIG. 548.

FIG. 548.—Portions of a *Tænia saginata*. (After Leuckart.) Natural size.



FIG. 549.

FIG. 549.—Head of *Tænia saginata*, retracted. Black pigmentation in and between the suckers. Unstained glycerin preparation.  $\times 30$ .



FIG. 550.

FIG. 550.—Segment of *Tænia saginata*. (After Leuckart.)  $\times \frac{1}{2}$ .

The "measles" are found usually in the muscles and the heart, more rarely in the other organs of cattle (*Cysticercus bovis*). They are somewhat smaller than the measles found in pork.

The development follows a course similar to that of *Tænia solium*. Malformations of this tapeworm are of very frequent occurrence.

The parasite is acquired by man through the eating of raw beef. It has not been definitely settled whether the "measles" of this worm occur in man, but some authors (Arndt, Heller) believe that such an occurrence does take place.

By means of its powerful suckers the parasite is able to cling very firmly to the intestinal wall. Stieda has observed a case in which a *tænia* 15 cm. long had penetrated through the wall of the duodenum into the pancreas, and had caused tissue-necrosis and hæmorrhage in its neighborhood.

*Tænia cucumerina* or *elliptica* is 15-20 cm. long, and possesses a head with rostellum and circle of hooklets. It is of very frequent occurrence in dogs and cats, but is rare in man. Its cysticeroid inhabits the louse and flea of the dog, more rarely the flea of human beings (*Grassi*).

*Tænia nana*, a small tapeworm of from 8 to 15 mm. in length, has a head with four suckers and a circle of hooklets. It has been observed chiefly in Egypt and in Italy. *B. Grassi* was able to obtain several thousands of specimens from two Sicilians who had suffered from severe nervous disturbances. According to his investigations, the *tænia* passes its entire development, from the embryo on, within the same host. *Viesconti* (*Rendiconti R. Istituto Lombardo*, xviii., 1886) found, at the autopsy of a young man from northern Italy, great numbers of *Tænia nana* in the lower portion of the ileum. In Germany it has been observed in only a few cases (*Mertens, Leichtenstern, Röder*).

*Tænia diminuta* (*Rud.*) or *flavopuncta* (*Weinland*), *minima* (*Grassi*) is a tapeworm, 20-60 mm. long, and has a head without hooklets. It is of common occurrence in rats and mice, and has also been observed in a few cases in man. According to *Grassi* and *Rovelli*, the measles live in a small butterfly, as well as in beetles.

*Von Linstow* has recently described as *Tænia africana* a large tapeworm with scolex devoid of hooklets, which he observed among the negroes of German East Africa.

Besides those which also occur in man, *tæniæ* are of frequent occurrence in the domestic animals, both in the carnivora and in birds, as well as in the herbivora.

*Tænia marginata* of the dog is a tapeworm, 1-5 m. long, provided with a double circle of hooklets. Its cysticercus forms cysts of varying size in and under the serous membranes of sheep, cattle, goats, and hogs.

*Tænia serrata* is a *tænia* found in the dog. It is 50-100 cm. long, and possesses a circle of hooklets. The cysticerci are found in rabbits and hares.

*Tænia caninus* is a tapeworm of the dog, 40-100 cm. long, and is provided with hooklets. It passes its cystic stage most frequently in sheep, where it seeks the central nervous system and forms cysts varying in size from that of a millet seed to that of a hen's egg, which contain great numbers of scolices. Its presence in the brain gives rise to the so-called "staggers" of sheep.

*Tænia plicata* (10-25 cm. long), *Tænia mamillana* (1-3 cm. long), and *Tænia perforata* (3-5 cm. long) occur in horses. *Tænia expansa* (4-5 m. long) and *Tænia denticulata* (25-80 cm. long) are the common tapeworms of cattle. Further, still other forms of *tæniæ* occur more rarely as parasites in sheep and cattle.

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§ 185. The *Taenia echinococcus* lives in the intestinal canal of the dog. It is 4–5 mm. long and possesses only four segments, the most posterior of these surpassing in length all the rest put together (Fig. 551).

The small hooklets have coarse root processes and are implanted upon a rather bulging rostellum. Their number runs from about thirty to fifty.

The **cyst-worm (hydatid)** alone is found in man. It results from the introduction of *tænia* eggs into the intestinal canal.

If the embryo wanders from the intestinal canal into any organ, it changes into a *cyst*, which is not capable of active motion. It consists of an outer *lamellated*, very elastic *cuticle* (Fig. 552, *a*) and a *parenchymatous* layer (*b*) lying internal to this, consisting of *granular masses* and cells, and containing *muscle-fibres* and a *vascular system*. When the cyst has reached about the size of a walnut (sometimes earlier), there are formed from the *parenchymatous* layer small *brood-capsules* (*c*) which

produce a great number of *scolices*. The first stage of these tapeworm heads consists of coarsely granular protoplasmic masses (*d*) lying in the wall of the brood-capsule; these develop further and show cavities (*e*) communicating with the cavity of the brood-capsule, and later become differentiated into a tapeworm head (*f*) furnished with a circle of hooklets. The head (*h*) which now protrudes into the lumen of the brood-capsule (*g, h*) is about 0.3 mm. long, possesses a rostellum with small, plump hooklets, four suckers, a water-vascular system, and numerous chalky bodies in its parenchyma. Frequently the anterior part of the body is telescoped into the posterior part (*g*).



FIG. 551.—Full-grown *Taenia echinococcus*. (After Leuckart.)  $\times 12$ .

In many cases the **echinococcus cyst remains single**. Its only change consists in an enlargement to the size of an orange or fist, through the formation of new brood-capsules and heads. The surrounding tissue forms a connective-tissue capsule, in which the cuticular cyst lies. The cavity of the cyst is filled with a clear fluid, which does not coagulate through boiling or on the addition of acids, and contains none or but little albumen, but on the other hand does contain sodium chloride, calcium oxalate, triple phosphates, uric acid, sugar (in the liver), and often also cholesterin. The brood-capsules are always situated on the inner surface, in case they are not mechanically dislodged; and are visible through the transparent parenchyma as small white points. Occasionally the cyst remains sterile.

In many cases **daughter-cysts** (Fig. 553, *c*) are formed. Their development proceeds in the depth of the cuticle independently of the real parenchymatous layer. Between two lamellæ of the cuticle there arises

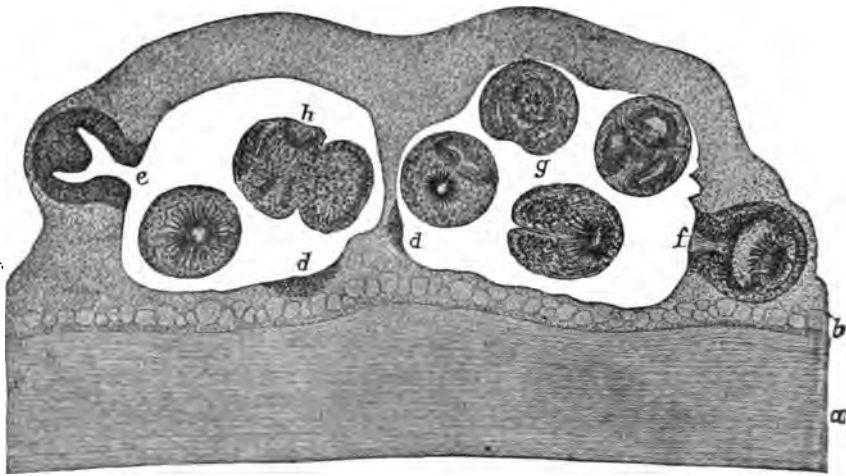


FIG. 552.—Wall of an echinococcus-cyst containing brood-capsules and scolices (alcohol, carmine). *a*, Chitinous membrane; *b*, parenchymatous layer with vesicular cells; *c*, brood-capsules; *d, e, f, g, h*, scolices in different stages of development.  $\times 100$ .

a collection of granules, which surround themselves with a cuticle, and thereby become the centre of a new set of layers. As the number of layers increases, the cavity grows larger and the contents become clear.



If the daughter-cysts grow they bulge out the wall of the mother-cyst like a hernial sac, until it finally gives way and liberates its contents. If they now pass outward by the side of the parent-cyst, they obtain from

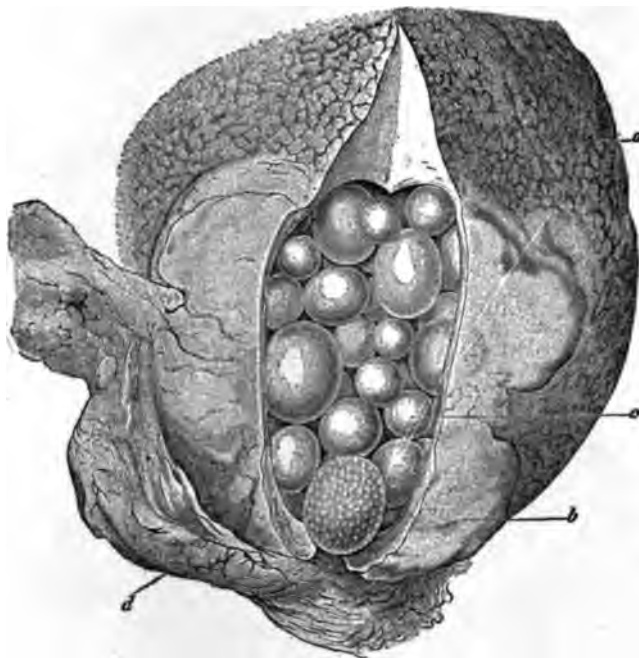


FIG. 553.—*Echinococcus hydatidosus*. a, Surface of liver; b, indurated connective tissue; c, daughter-cysts within a parent-cyst, which has been opened by an incision; d, adhesions. Three-fifths natural size.

the parenchyma in which they lie an external capsule of connective tissue, and then produce brood capsules in the same manner as the primary cysts arising from the six-hooked embryos.

An echinococcus with an *exogenous proliferation* is called **echinococcus granulosus** (*scolecipariens* Küchenmeister), or sometimes also **echinococcus veterinorum** from the fact that it is of frequent occurrence among the domestic animals.

A second compound form of the echinococcus is the **echinococcus hydatidosus**. It is characterized by the presence of inner *daughter-cysts* (Fig. 553, c). According to statements made by Naunyn, and also confirmed by Leuckart, the scolices and brood-capsules undergo a cystic metamorphosis, and so become changed into daughter-cysts which occasionally produce grand-daughter cysts. Through the formation of numerous daughter-cysts the chief cyst may attain a very large size.

The *infection of man* follows the ingestion of the eggs of the *tænia* which occurs in dogs. The cysts are most often found in the liver, but the echinococcus occasionally occurs in the most diverse organs—for example, in the lungs, spleen, kidneys, intestine, in a bone or in the heart. With the exception of the disturbance of the tissues from pressure and of the local inflammation which it causes (the latter leading to the formation of a connective-tissue capsule in many organs) the cyst often

produces no harmful effects upon the affected individual. It often dies on attaining a certain size (that of a walnut to that of an apple), the fluid is absorbed, the cyst contracts, and there remains within it a fatty, cheesy detritus, which often calcifies to a mortar-like mass. The hooklets are preserved for a very long time.

In other cases the echinococcus becomes larger, particularly when endogenous or exogenous daughter-cysts develop. It may become dangerous through its size alone. Severe inflammations are occasionally produced, particularly after trauma or after rupture of the cyst into one of the body-cavities. Rupture into a blood-vessel may also occur and lead to the metastasis of cysts and an embolic blocking of vessels. In more favorable cases rupture may take place externally or into the intestines.

The spontaneous spread of brood-capsules and scolices in the same



FIG. 554.—Transverse section of an *Echinococcus multilocularis*. *a*, Alveolar echinococcus tissue; *b*, liver tissue; *c*, cavity produced by softening; *d*, fresh nodules. Natural size.

host, as well as the experimental transplantation of the same into another host (Alexinsky) may lead to the formation of new cysts.

The form of the parasite known as *echinococcus alveolaris* or *multilocularis* presents itself as a hard tumor, situated usually in the liver, rarely in other organs (brain, spleen, adrenal), and possesses an alveolar structure (Fig. 554), in that a firm, dense connective-tissue mass encloses numerous cavities. Its contents are translucent and gelatinous, or consist of fluid and a gelatinous substance. The cavities are in part spherical and in part irregular in shape. Usually, through the softening and disintegration of the parenchyma, ulcerative cavities (*c*) are formed. In other places the tissue is fibrocaseous, necrotic or calcified, or is impregnated with bile. At times the caseation of the proliferating tissue is the most prominent feature of the process; at other times the alveolar structure. When the development of the colonies has progressed further, there appear in the tissue gray and yellowish nodules (*d*) in which cavities containing colloid plugs (chitin-cysts and coils) are developed.

The exquisite alveolar structure has given rise to the theory that this form of echinococcus is an alveolar, colloid-containing tumor of the liver. Virchow first recognized the true nature of the condition, and demonstrated that the so-called colloid masses were echinococcus cysts.

According to the investigations of Melnikow-Raswedenkow the alveolar echinococcus is to be regarded as a different species, which increases in the tissue of the host in a peculiar manner, suggesting the mode of development of the Trematodes; and in many cases spreads by both hæmatogenous and lymphogenous metastases from the primary focus of development to other organs (lymph-glands, lungs, brain).

The embryo migrating from the intestine into the liver becomes changed into a multilocular chitinous coil, which possesses on both inner and outer sides granular masses of protoplasm, from which in part *scolices*, and in part *ovoid embryos* develop. These, through virtue of their motility, become distributed in the tissues and give rise to proliferations of granulation tissue with the formation of epithelioid cells and multinuclear giant-cells, terminating partly in tissue-indurations and partly in caseation. The latter process is particularly prominent in metastatic foci. Among the structures which arise from the granular protoplasm of the parasite there may be distinguished the following forms: (1) ovoid embryos with thin homogeneous membrane; (2) embryos with thick fibrous capsules; (3) scolices.

The embryos which are capable of migration are to be found inside of the chitin-cysts as well as free between the tissue-cells. A part of the embryos wandering thence into the connective tissue of the organ develop within the vessels into complicated chitin-cysts or coils which again form an after-growth of embryos; another part die and are taken up by phagocytes or are infiltrated and disintegrated.

Scolices form from the granular protoplasm of the embryo (proscolices) inside of the chitin-structure as well as outside of the same. The proscolices entering the tissues may also be changed into chitin-cysts.

The life-history of the alveolar echinococcus outside of the parenchyma of the organ is unknown; the feeding to dogs has given no positive results. It appears that the embryos and scolices of the same are not capable of development in the intestine of the dog.

The ordinary echinococcus is widely distributed, though not very common. It is of most frequent occurrence in Iceland, where the inhabitants live in very close association with dogs. The alveolar echinococcus has been observed chiefly in Switzerland, South Germany, Austria, and in Russia.

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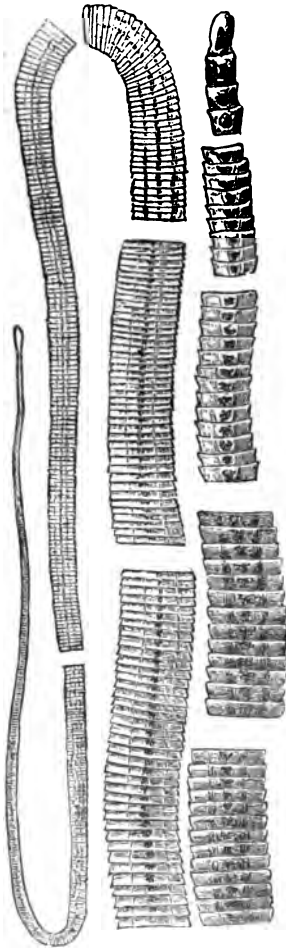


FIG. 555.

FIG. 555.—*Bothriocephalus latus*. (After Leuckart.) Natural size.



FIG. 556.

FIG. 556.—Head of *Bothriocephalus latus* of Bremser. (After Heller.) Enlarged.

§ 186. *Bothriocephalus latus* (Bremser) or **pithead** is the most formidable tapeworm of man, measuring from 5–8 metres in length, and consisting of three thousand to four thousand short but broad segments (Fig. 555), which are broadest in the middle region and narrower again at the end. The length of the largest segment is about 3.5 mm., the breadth about 10–12 mm.

The head (Fig. 556) has a long oval or club shape, is about 2.5 mm. long and 1 mm. broad. It is somewhat flattened, and possesses on each lateral margin a slit-like depression, and is mounted upon a filiform neck.

The body is narrow and flat like a ribbon, with the exception of the central parts of the segments which project somewhat outward. At this spot the uterus is found, in the shape of a single canal, which forms a number of coils (Fig. 557, *m*). When the eggs collect here in great numbers the lateral coils of the uterus arrange themselves in folds, so that a remarkable rosette-like appearance is produced. The sexual openings lie in the middle line of the ventral surface, near to the anterior border of the segment, the female orifice (*o*) being close behind the male opening (*f*).

The ovary (*g*) is a double organ which lies in the middle layer; the



yolk-chambers (*h*), on the other hand, are located in the cortical layer. The shell-gland (*k*) lies behind the collecting-tube (*i*) of the yolk-cham-



FIG. 557.—Median portion of a proglottis of *Bothriocephalus latus*, seen from the dorsal surface. The cortical layer of the segment has been removed except a border on each side, and the middle layer thus exposed. (After Sommer.) *a*, Lateral vessels; *b*, testicular vesicles; *c*, testicular canaliculi; *d*, seminal ducts; *e*, posterior, *f*, anterior hollow-muscle apparatus (cirrus-sac of vas deferens); *g*, ovary; *h*, yolk-chambers lying in the cortical area; *i*, collecting-duct of yolk-stalk, branches of which lead ventrally to the yolk-chambers; *k*, shell-gland; *l*, beginning of the uterus; *m*, loop of uterus filled with eggs, the orifice of uterus opening on the anterior surface; *n*, vagina; *o*, vaginal opening.  $\times 35$ .

bers. The testicles consist of clear vesicles (*b*) which lie in the lateral portions of the middle layer, and communicate by means of fine canals (*c*) with the vas deferens (*d*), which terminates in the cirrus-sac (*e, f*).

The eggs (Fig. 558) are oval, and are about 0.07 mm. long and 0.045 mm. broad. They are surrounded by a thin, brown shell, the anterior pole of which forms a sharply outlined cap-like cover.

The *Bothriocephalus latus* occurs chiefly in Switzerland, in the northeastern parts of Europe, in Holland and in Japan, and lives, as does the *Tenia*, in the intestine of man. According to Bollinger it is rather frequent in Munich. The first stage of development of the eggs takes place in water. After the lapse of months there develops an embryo (*Oncosphara*) armed with six hooklets and covered with ciliae (Fig. 559). This de-



FIG. 558.



FIG. 559.

FIG. 558.—Eggs of *Bothriocephalus latus*, the one at the right having been emptied of its yolk-contents. (After Leuckart.)

FIG. 559.—Free embryo of *Bothriocephalus latus* with ciliated envelope. (After Leuckart.)

velops, in some intermediate host as yet unknown, into a measle (*Plerocercoid*), which, according to the investigations of Braun in the Russian Baltic provinces, seeks out as second intermediate host the pike or tadpole, and develops in the muscle or internal organs of these animals into a sexless tapeworm. According to Grassi and Parona, the measle of *Bothriocephalus latus* in Italy occurs in the pike and in the river-perch. In Japan it is found most frequently in the *Onchorhynchus Perryi* (Ijima, Leuckart). Zschokke found it in the Lake of Geneva in the following forms of fish: *Lota vulgaris*, *Perca fluviatilis*, *Salmo umbla*, *Esox lucius*, *Trutta vulgaris*, and *Trutta lacustris*. It is found most often in the tadpole (*Lota vulgaris*) and in the perch (*Perca fluviatilis*). Should the measle gain entrance, through the ingestion of the fish mentioned, into the intestinal canal of man, it again attains sexual maturity. According to Braun and Parona the measles may also be brought to development in both dogs and cats. The presence of *Bothriocephalus* in the intestine gives rise to a gradually increasing anæmia, which resembles pernicious anæmia. The diminution of the red blood-cells and of the hæmoglobin content of the blood is probably due to the fact that after the death of the tapeworm poisonous products arise having an injurious action upon the blood-corpuscles.

***Bothriocephalus cordatus*** (Leuckart) is a tapeworm, of 80–115 cm. long, and has a heart-shaped head, whose sucking-grooves are flattened. The breadth of the ripe segments is about 7–8 mm.; the length, about 3–4 mm. In Greenland and Iceland it is a frequent parasite of the dog, seal, and walrus, and is found occasionally in man. The measles likewise occur in fishes.

***Bothriocephalus Mansoni* (Cobbold) or *liguloides*** (Leuckart) is the measle (plerocercoid) of a tapeworm which has been observed a few times (Manson, Ijima, Murata) in the body-tissues and in the descending urinary passages or in the urine. Its origin is not known.

### Literature.

#### (*Bothriocephalus latus*.)

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**Braun**: Virch. Arch., 88 u. 92 Bd.; Zur Entwicklungsgeschichte des breiten Bandwurmes, Würzburg, 1885; Ueber den Zwischenwirth des breiten Bandwurmes, Würzburg, 1886; Die thier. Parasiten des Menschen, Würzburg, 1895.  
**Grassi, B., e Rovilli**: Contrib. alla studio dello sviluppo del Botriocefalo lato. Giorn. della R. Accad. di Med., 1887, ref. Cbl. f. Bakt., iii., 1888.  
**Leuckart**: L. c., und Zur *Bothriocephalus*-Frage. Cbl. f. Bakt. u. Parasitenk., i., 1887.  
**Parono**: Rendiconti Ist. Lomb., vol. xix.  
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### B. NEMATHELMINTHES (ROUND WORMS).

§ 187. All the **round worms** which occur as parasites belong to the **Nematoda**. They possess a slender, cylindrical, elongated, at times filiform body without segments or appendages. The cuticle is thick and elastic. The mouth opening is found at one extremity, and is provided

sometimes with soft and sometimes with horn-like lips. The elongated intestine, together with the pharynx and chyle-stomach, extends through the entire body-cavity (Fig. 560) and opens upon the ventral surface a short distance from the (usually) awl-shaped posterior extremity. The sexual organs and their openings are also found on the ventral surface. The female sexual orifice is located at about the middle of the body, less frequently near the anterior or posterior extremity (Fig. 560, *A*, *a*). In the male the sexual opening and the anus are located together (*B*, *c*). The chitinous covering of the lower gut forms in the male the means of clinging during the act of copulation. The males are usually smaller than the females. The development is direct, and the metamorphoses are not striking. The nematodes occurring in man are in part harmless parasites of the intestine, and in part very dangerous, sometimes even fatal, parasites of various organs.

§ 188. *Ascaris lumbricoides*, the common round-worm (Fig. 560) is a light-brown or reddish, cylindrical worm with tapering ends. The female (*A*) is 25-40 cm. long, the male (*B*) is much smaller, and the posterior extremity of the latter is bent in the form of a hook and provided with two spicules (*c*) or chitin processes.

The mouth opening (*b*) is surrounded by three muscular lips bearing fine teeth. The female sexual opening (*A*, *a*) lies anterior to the middle of the body. The eggs which the mature female contains in enormous numbers possess in their fully developed condition a double shell (Fig. 561) and around this an albuminous envelope. They are about 50-70  $\mu$  in length. The worm inhabits the entire intestinal tract, but most frequently the small intestine. It is the most common parasite of man, and is found frequently in very great numbers. When mature females are present the faeces contain the eggs in great numbers. These are very resistant to external influences, for example, to drying and freezing.



FIG. 560.

FIG. 561.

FIG. 560. — *Ascaris lumbricoides*, (After Peris.) *A*, Female; *B*, male. Natural size. At *a* is the female sexual orifice; *c*, the two spicules of the male; *b*, the (enlarged) cephalic end with the three lips.

FIG. 561. — Egg of *Ascaris lumbricoides*, with shell and albuminous covering. (After Leuckart.)  $\times 300$ .



The eggs require no intermediate host (Lutz, Leuckart, Grassi, Epstein). Man is infected by the ingestion of eggs which have been expelled from the bowel and have matured in the fæces. According to feeding-experiments which Epstein carried out on human beings with eggs which had been cultivated in damp fæces for a long time, the round-worm attains its maturity in from ten to twelve weeks after the ingestion of the eggs. At this time the male is 13–15 cm. long, and the female from 20–30 cm. Their presence in the intestine does not cause any noticeable disturbance. Only when present in large numbers do they sometimes, especially in children, cause intestinal catarrh, vomiting, nervous disturbances and convulsions. Occasionally the worm crawls into normal and pathological openings in the wall of the intestinal canal, and in this way causes trouble. Thus, when it crawls into the ductus choledochus, it may produce bile-stasis. If it penetrates through an ulcer into the peritoneal cavity or into a hernial sac, it may excite inflammation of the tissues concerned. According to Leuckart it may also penetrate the uninjured intestinal wall. It is very frequently passed with the stools *per anum*, but at times *per os* in vomiting. From the pharynx it may wander into the larynx.

In the domestic animals ascarides are of frequent occurrence. *Ascaris lumbricoides* is found in swine (*Ascaris suilla*) and in cattle (*Ascaris vituli*). *Ascaris megalocephala*, a round worm whose female is 18–37 cm. long, is a common parasite of the horse and donkey. *Ascaris mystax*, whose female reaches a length of 12 cm., is found frequently in dogs and cats, and has also been observed in man. Various species, designated as *Heterakis*, occur in birds. *Heterakis maculosa*, the round worm of pigeons, may cause the death of the pigeon when occurring in large numbers within its intestine.

### Literature.

#### (*Ascaris Lumbricoides*.)

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 Grassi: Intorno all' *Ascaris lumbricoides*. Gazz. degli Ospetali, ii., 1881, u. Cbl. f. Bakt., iii., 1888; Trichocephalus- und Ascarisentwicklung. Ibid., i., 1887.  
 Huber: Bibliographie der klin. Helminthologie, München, 1898.  
 Kitt: Lehrb. d. path. anat. Diagnostik, ii., Stuttgart, 1895.  
 Leuckart: Uebergangsweise des *Ascaris lumbricoides*. Cbl. f. Bakt., ii., 1887.  
 Lutz: Zur Frage der Invasion von *Taenia elliptica* u. *Ascaris lumbricoides*. Cbl. f. Bakt., ii., 1887; Uebertragung des menschlichen Spulwurms. Ib., iii., 1888.  
 Peiper: Thierische Parasiten. Ergebn. d. allg. Path., iii., 1897.  
 Saltykow: Ascaridosis hepatis. Zeitschr. f. Heilk., xxi., 1900.

§ 189. *Oxyuris vermicularis*, *awl-tail*, *pinworm*, or *threadworm* is a small round worm (Fig. 562), the female being about 10 mm. long (*a*, *b*) and pointed at the caudal extremity like an awl, while the male is about 4 mm. long (*c*) with a blunt posterior end, the anus being provided with a spiculum.

The eggs (563, *a*), which the body of the female often contains in very great numbers, are 50  $\mu$  long and 24  $\mu$  broad, have a flat and a curved surface, and a shell which is covered by a thin albuminous layer. *Oxyuris vermicularis* inhabits the large intestine and the lower portion of the small intestine. According to Zenker and Heller only the impregnated mature females are found in the large intestine, the young individuals and the males remain in the small intestine. They occur very frequently in larger or smaller numbers. At night they often wander from the rectum over the anal region, and may enter the vagina; they excite



itching of the affected parts. The scratching thus produced sometimes leads to dermatitis, erections, masturbation, etc.

For the development of the eggs (Fig. 563 *a-c*), it is necessary after their expulsion with the feces that they again be taken into the stomach of man or beast. It is very probable that the original host may again infect himself with oxyuris, in that, for example, the eggs becoming attached to his finger during the act of scratching may later get into his mouth.

The eggs are very resistant to drying, and in this condition may be widely scattered.

§ 190. *Anchylostoma duodenale* (*Dochmius duodenalis*, or *Strongylus duodenalis*, or *Uncinaria duodenalis*, also *Uncinaria Americana* [Stiles]), Hook-worm, is a small worm belonging to the family of *Strongylides*, which inhabits the upper part of the small intestine (Fig. 564). The cylindrical body of the female is 5-18 mm. long, that of the male 6-10 mm. The cephalic end (Fig. 565) is curved toward the dorsal surface, and possesses a bellied mouth-capsule (*d*). It is almost completely divided dorsally, and the cleft is covered by two chitinous layers. On the ventral border there are four incurving teeth (*b*), on the dorsal border two teeth which are perpendicularly placed (*c*), all being held together by chitinous bands.

The male is provided at its caudal extremity with a threefold bursa (Fig. 564, *i*), and two thin, fishbone-like spicules (*p*). In the female the posterior end is pointed, and bears an awl-shaped spine; the vulva lies posterior to the body centre. The oval



FIG. 563. — Eggs of *Oxyuris vermicularis* in different stages of development. (After Zenker and Heller.) *a, b, c*, Segmentation of yolk; *d*, tadpole-shaped embryo; *e*, worm-shaped embryo.  $\times 250$ .



FIG. 562. — *Oxyuris vermicularis*. *a*, Sexually mature female; *b*, female full of eggs; *c*, male. (After Heller.)  $\times 10$ .

eggs (Fig. 566) are 44-67  $\mu$  long, 23-40  $\mu$  broad. They undergo the first stages of cleavage in the human intestine (*a-d*), develop further in muddy water (*e, f*), and may then, if brought into the human intestinal tract, develop again into sexually mature animals. With its teeth the worm works its way into the mucous membrane as far as the submucosa, and sucks itself full of blood. Its point of attack is distinguishable later by a small ecchymosis in the middle of which there is a white spot with a central perforation. Occasionally there are found in the intestinal mucosa small cavities filled with blood, within each of which there lies a coiled-up worm. The parasites, when present in large numbers, cause a continuous and serious loss of blood, which may

lead to the most severe forms of anæmia (*Egyptian chlorosis*), but they are not infrequently found in individuals who present no symptoms of

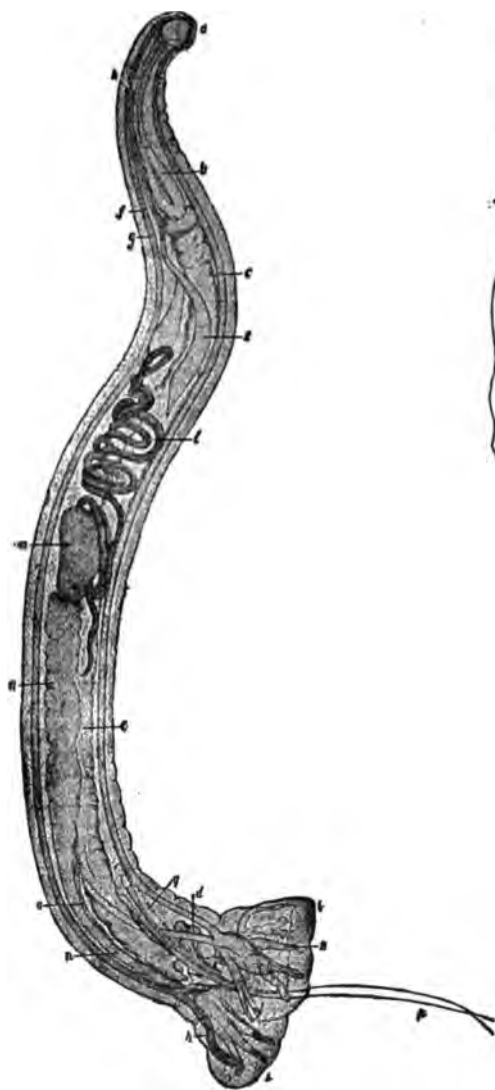


FIG. 564.

FIG. 564.—Male of *Anchylostoma duodenale*. (After Schulthess.) a, Head with mouth-capsule; b, esophagus; c, intestine; d, anal-glands; e, cervical glands; f, skin; g, muscle-layer; h, porus excretorius; i, triple bursa; k, ribs of the bursa; l, testicular canal; m, seminal vesicle; n, ejaculatory duct; o, groove of latter; p, penis; q, penis sheath.  $\times 18$ .

FIG. 565.—Cephalic end of *Anchylostoma duodenale*. (After Schulthess.) a, Mouth-capsule; b, teeth of ventral border; c, teeth of dorsal border; d, mouth cavity; e, skin protuberance on ventral side of head; f, muscular layer; g, dorsal groove; h, esophagus.

FIG. 566.—Eggs of *Anchylostoma duodenale*. (After Perroncito and Schulthess.) a-d, Different stages of segmentation; e, f, eggs with embryos.  $\times 200$ .

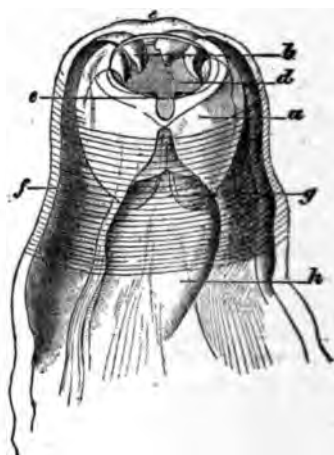


FIG. 565.

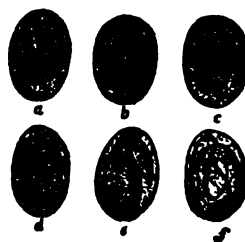


FIG. 566.

disease. The parasite is very common in the tropics, and also in Japan. According to Griesinger and Bilharz about one-quarter of the native

Egyptians suffer from this disease. The parasite was very often observed in the workmen engaged in the Saint Gotthard tunnel. According to Menche and Leichtenstern the brick-fields of the Rhine provinces are to a great extent infected with anchylostoma (brick-burner's anæmia). (For the distribution of *Uncinaria Americana*, see Stiles, Bull. U. S. Dept. of Agric., 1902.)

**Eustrongylus gigas**, a palisade-worm of red color, whose female reaches a length of 1 metre, is a very rare parasite, which has been observed only a few times in the kidney-pelvis of man. It occurs very frequently in dogs. It possesses a mouth-opening with six papillæ; the male has on its posterior extremity a bursa with a single spiculum. The eggs are oval, 0.06 mm. long, and provided with a rough albuminous capsule.

**Strongylus longevaginatus**, a thread-like, white worm, 26 mm. long, was once observed in the lung of a boy.

In the **domestic animals** *Strongylides* occur in much greater numbers than in man, and are in part inhabitants of the intestine, and in part of the lungs (Müller, "Die Nematoden der Säugethiere," *Deut. Zeitschr. f. Thiermed.*, xv., 1886).

*Dochmius trigonocephalus* and *Dochmius stenocephalus* occur in the intestine of dogs, and give rise to anæmia.

*Strongylus armatus* is a common parasite of the horse, which enters the intestinal tract as an embryo, bores into the intestinal wall (*Ost*), thence into the liver, by way of the portal vein, and further into the lungs and the organs of the major circulation. Following this migration, it may develop in the most diverse organs and cause the formation of fibrous nodules, which become calcified after the death of the parasite enclosed in them. In the intestinal wall it may develop after direct migration or after embolic lodgment in the part, and leads to the formation of cavities, from which it again breaks through into the intestinal lumen. In the mesenteric arteries it attains sexual maturity, and causes thrombosis and the formation of aneurisms. The male of the mature worm is 20–30 mm. long; the female, 20–55 mm.

*Strongylus tetracanthus*, which inhabits the large intestine of the horse, causes a hæmorrhagic enteritis when present in large numbers.

*Strongylus paradoxus* is an extremely common parasite of the lungs of hogs. *Strongylus capillaris*, *Str. commutatus*, and *Str. filaria* are frequent parasites of the lungs of goats and sheep, and different species may be present in the same lung at one time (Schlegel, "Die durch Strong. capillaris verursachte Lungenwurmseuche der Ziege," *Arch. f. wiss. Thierheil.*, 25 Bd., 1899). The latter causes in sheep a bronchitis and nodular proliferating pulmonary inflammations; through the swallowing of many embryos inflammations of the intestine may also be produced.

*Strongylus rufescens* and *Str. paradoxus*, *Nematodius oris pulmonalis* (Lydtin), or *Pseudalius oris pulmonalis* (Koch) are also inhabitants of the lungs of sheep, the last-named causing a pseudotuberculosis. *Str. commutatus* and *Str. pusillus* occur in the lungs of the hare and rabbit; *Str. syngamus* and *bronchialis* in the trachea of birds; and excite inflammations. *Str. micrurus* (Stroë, "Bau von Strongylus micrurus," *Deut. Zeitschr. f. Thiermed.*, xviii., 1892) occurs in cows and calves, in arterial aneurisms as well as in the respiratory passages.

*Strongylus pusillus* causes in cats a pulmonary disease resembling tuberculosis (Jeanmair, "Ueber die hist. Veränd. der Lunge bei der verminösen Pneumonie der Katze und des Hasen," Inaug.-Diss., Freiburg, 1900). *Syngamus trachealis* (Klee, "Der gepaarte Luftröhrenwurm des Geflügels," *Deut. Thierärztl. Wochenschr.*, 1899) is a dangerous parasite of birds, particularly of pheasants, in the trachea of which it appears in great numbers, and attaches itself to the mucous membrane. It is easily recognized by its red color. Similar to the last-named is *Syngamus bronchialis*, which has been observed a few times in geese and ducks.

## Literature.

(*Anchylostoma*.)

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 Stiles: Prevalence and Geographic Distribution of Hookworm Disease (Uncinariasis or Anchylostomiasis) in the United States. Bull. of Hyg. Lab., Pub. Health and Marine-Hospital Service of the United States, 1903.  
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 Zinn u. Jacoby: Anchylostomum duodenale, Leipzig, 1898 (Lit.).

§ 191. *Anguillula intestinalis* (Fig. 567) is a worm of 2.25 mm. length, which is found in the intestine, particularly in the *tropics*, and in

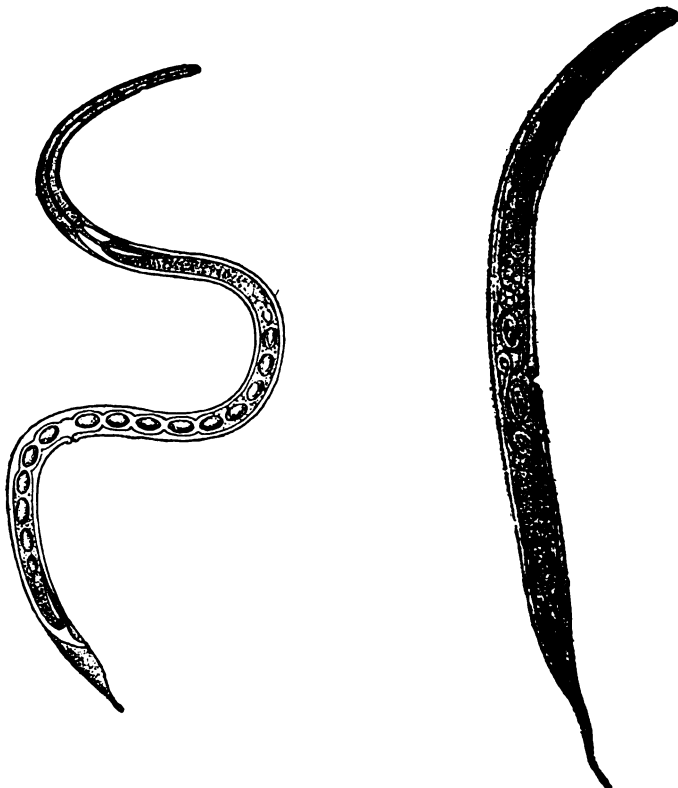


FIG. 567.—*Anguillula intestinalis*.  
(After Braun.)

FIG. 568.—Female of *Anguillula stercoralis*, with eggs and embryos. (After Perroncito.)  $\times 85$ .

*Italy*, and has been occasionally observed in Switzerland, Germany, Belgium, and Holland (probably transported from Italy), under similar con-



ditions as the *Anchylostoma duodenale*. According to the observations of Leuckart, Golgi, Grassi, Leichtenstern, Zinn and others, the *Anguillula intestinalis* is a hermaphrodite, the eggs of which develop even in the intestine to embryos of 0.2 mm. in length; and in the presence in the intestine of numerous parent-worms are found in the fæces in great numbers. In the stools they become changed within about twelve hours into filaria-like larvæ, which, when gaining entrance into the human intestine, again grow into parasitic anguillulæ, which are again able to produce eggs capable of development. In addition there also occurs a development with an intermediate sexual generation, a heterogony.

In the event of a sexual development the embryos grow outside of the body in about three days into sexually mature animals (female 1.2 mm. long, male 0.88 mm.) which are known as *Anguillula* or *Rhabditis stercoralis* (Fig. 567), and were formerly regarded as a separate species. The embryos of the separate sexual individuals develop into filaria-like larvæ, which, entering the intestine of man, again grow into parasitic anguillulæ.

According to Leichtenstern and Zinn the filaria-like larvæ of the direct development are more resistant than those of the sexual. The sexual mode of multiplication occurs particularly in the anguillula, coming from the tropics, while in the indigenous form (brick-laborers of Germany, Belgium, Holland) the direct metamorphosis predominates. Leichtenstern has explained this by the assumption that the tropical anguillula after its transportation into a temperate zone has adapted itself to the less favorable climatic conditions of the latter in such a manner that the anguillula of the temperate zone favors more the much simpler mode of development which is the more independent of the climate—namely, the direct transformation of the embryo into the filaria-shaped larvæ, which in turn grow directly into parasitic anguillulæ.

According to the statements of various authors *Anguillula stercoralis* when present in large numbers causes diarrhœa. According to Normand, Grassi, Golgi, Leichtenstern, and others, the worms are found chiefly in the upper parts of the small intestine. According to Leichtenstern and Askanazy the mature animals and the larvæ penetrate not only into the crypts of Lieberkühn, but also into their epithelium and into the connective tissue of the mucosa, and in individual cases may break through the muscularis mucosæ. The mother animals lay their eggs in the intestinal crypts. The embryos when hatched out wander out into the intestine.

#### Literature.

##### (*Anguillula Stercoralis and Intestinalis.*)

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Thayer: On the Occurrence of Strongyloides Intestinalis in the United States. Journ. of Exp. Med., 1901.

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§ 192. *Tricocephalus dispar*, the *whipworm*, is a common and relatively harmless parasite, though according to Askanazy it sucks blood from the intestinal mucosa. It inhabits the cæcum and the neighboring portions of the intestine. It is found also in the domestic animals. The

male and female are about 4–5 cm. in length (Fig. 569). The anterior body-half (*a*, *b*) is very thin, thread-like; the posterior, which bears the sexual organs (*f*, *g*, *l*, *o*, *p*) is much thicker, in the female (*B*) cylindrical, and in the male (*A*) rolled up and provided with a spiculum (*g*).

The eggs (Fig. 570) are an elongated oval, 50  $\mu$  long, and possess a thick brown shell, which shows at both poles a peg-shaped, glassy swelling.

The first stage of the development of the embryos takes place in water and in moist earth. It advances slowly, even in summer lasting four to five months, and in the colder months of the year much longer. The eggs are very resistant to cold and drying. (For the literature see Huber, "Bibliographie der klin. Helminthologie," München, 1893, p. 213; Askanazy, "Der Peitschenwurm," Deut. Arch. f. klin. Med., 57 Bd., 1896; Heine, "Anatomie d. *Tricocephalus*," Cbl. f. Bakt., xxviii, 1900).

§ 193. *Trichina spiralis* occurs in two forms—the trichina of the intestine and the trichina of the muscles.

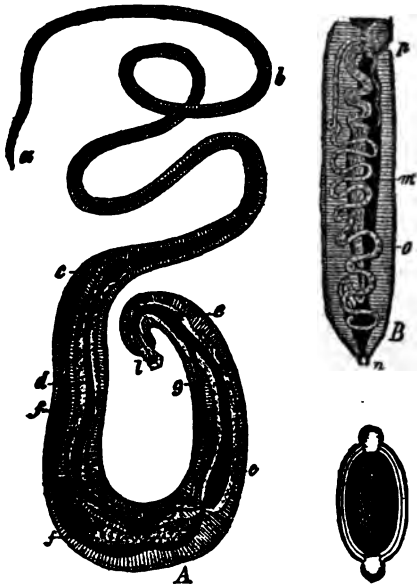


FIG. 569.

FIG. 569.—*Tricocephalus dispar*. (After Küchenmeister and Zörn.) A, Male; B, caudal end of female; *a*, cephalic end; *b*, anterior portion of body with oesophagus; *c*, stomach; *d*, intestine; *e*, cloaca; *f*, seminal duct; *g*, penis; *l*, bell-shaped penis-sheath, with end of penis; *m*, intestine of the female; *n*, anus; *o*, uterus; *p*, vaginal opening.  $\times 9$ .

FIG. 570.

FIG. 570.—Egg of *Tricocephalus dispar*. (After Heller.)  $\times 315$ .

571) is the sexually mature form, and is a small, white, hair-like worm scarcely visible to the naked eye. The female (*A*) is 3 mm. long, the male (*B*) is much smaller. The posterior part of the body is elongated in both sexes, and in the male (*B*) is provided on the dorsal half with two conical terminal pegs, which are directed toward the belly and are separated from each other by four knob-like papillæ. Instead of a spiculum the muscular cloaca is protruded outward during copulation.

The intestinal canal begins with a muscular mouth, which becoming wider passes into the oesophagus, which throughout its entire length is surrounded by the so-called cell-body—that is, by rows of large cells. The stomach, which follows the oesophagus, is a flask-shaped dilatation of the intestine, and is lined with finely granular cells. The stomach passes

without any essential change of structure into the intestine, which in the male unites with the seminal duct at the posterior end to form the cloaca.

The testicles consist of a pouch, which begins near the caudal end as a blind sac, proceeds as far forward as the cell-bodies, and bending there, passes over into the seminal duct.

The sexual organs of the female (*A*) consist of a single ovary, a uterus and a vagina, which opens externally at the junction of the first and second quarters. The ovary likewise forms a pouch lying close to the posterior end of the body, in which the round eggs develop. The pouch passes anteriorly into the sac-shaped uterus.

The eggs develop within the uterus into embryos which are set free at birth.

The **muscle-trichina** (Fig. 572) is a worm 0.7-1 mm. in length, which lives in the muscles of the body. It is usually rolled into a spiral and lies in a capsule, which occasionally contains lime-salts. Between the coils of the worm there is a finely granular mass.

A single capsule may contain three to five trichinæ.

If a piece of muscle containing living trichinæ is taken into the stomach of a host—for example, man—the capsule is dissolved and the trichinæ are set free. In the intestinal canal they attain sexual maturity within two and a half days, when copulation takes place. On the seventh day after the ingestion of muscle trichinæ the birth of embryos begins, which continues some time, even for weeks. A single female trichina may bear from one thousand to thirteen hundred young. According to Pagenstecher, Chatin, Cerfontaine, and Askanazy, the female trichinæ penetrate into the intestinal villi and deposit the embryos in the chyle-vessels, whence their migration begins. To what extent they are swept along passively by the lymph, or to what extent active migration is concerned in their spreading, is a difficult matter to determine. When arriving in the muscles they penetrate the primitive fibres, bring the adjacent contents of the fibre to degeneration, and grow in about fourteen days to fully developed muscle trichinæ. In the neighborhood of the trichinæ there occurs a proliferation of the muscle-nuclei and an inflammation of the connective tissue. At first the muscle-trichinæ are enclosed only by the sarcolemma, which appears thickened and hyaline about them. Later there occurs in the neighborhood an inflammatory proliferation of granulation tissue which leads to the production of connective tissue on the outside of the sarcolemma and penetrates even within the



FIG. 571.—Sexually mature trichinæ. *A*, Female; *B*, male. (After Leuckart.)  $\times 120$ .

sarcolemma tube, the muscle-nuclei being destroyed. Fat cells may appear later in the connective tissue of the capsule, the development of the latter being especially marked at the poles.

The intestinal trichinæ have a limited life of from five to eight weeks. The muscle-trichinæ, on the other hand, may live for a very long, possibly an unlimited time—that is, until the death of the affected individual; or at any rate for years, although, according to Ehrhardt, a few may die

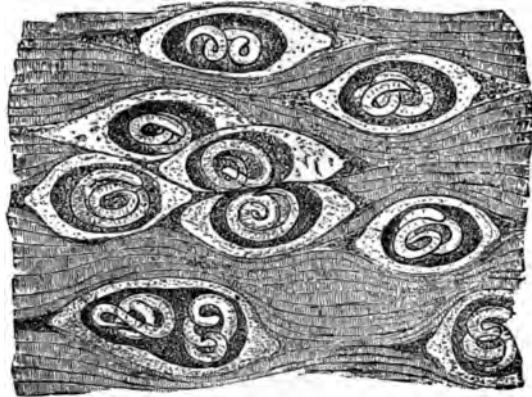


FIG. 572.—Encapsulated muscle trichinæ. (After Leuckart.)  $\times 60$ .

before the encapsulation. After some time there frequently occurs a deposition of lime-salts in the capsule, especially at the poles, causing it to appear glistening-white by reflected light, and cloudy and dark by transmitted light. In rare cases the trichinæ after dying also become calcified.

Trichinæ have been observed, besides in man, also in the hog, cat, dog, rat, mouse, marmot, polecat, fox, marten, badger, hedgehog, and raccoon. Through the feeding of trichinous meat muscle-trichinæ may also be developed in rabbits, guinea-pigs, sheep, dogs, etc. Man becomes infected through the eating of uncooked pork. The invasion of the trichinæ produces various phenomena in man. The introduction of trichinous meat into the intestine is followed by the symptoms of an intestinal catarrh. With the invasion of the muscles there are produced pain, swelling, œdema, paralysis, and not infrequently fever. The symptoms are most severe in the fourth and fifth weeks. Death not infrequently results.

The trichinæ are found most abundantly in the diaphragm, tongue, intercostal muscles, the muscles of the neck and larynx, the lumbar muscles, and are scattered most sparsely in the distant muscles of the extremities. They are usually most numerous about the insertions of the tendons.

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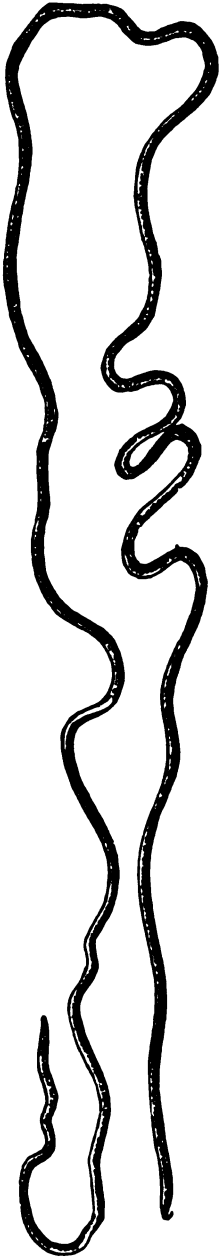


FIG. 573.

FIG. 573.—*Filaria sive Dracunculus medinensis*. (After Leuckart.) Natural size.



FIG. 574.

FIG. 574.—Embryo of *Filaria Bancrofti*, known as *Filaria sanguinis hominis*. (After Lewis.)  $\times 400$ .

§ 194. *Filaria* or *Dracunculus medinensis*, the Guinea-worm (Fig. 573), is a thin, thread-like female worm from 60 to 100 cm. in length. The males (observed by Charles) which were attached to female filariæ, were only 4 cm. long. The anterior extremity is rounded off, while the posterior tapers into a pointed tail which is curved toward the belly. The external covering consists of a firm cuticle, which at the cephalic end is thickened in the form of a shield. The intestinal canal is narrow and has no anus. The uterus, filled with young, takes up nearly the whole of the body-cavity. The embryos, which are set free by the bursting of the mother-worm, have a firm cuticle and an awl-shaped tail. As intermediate host, the embryos seek out small crustaceæ, in which they are probably taken into the stomach of man with the drinking-water. In Africa and Asia the worm is of frequent occurrence. It develops in the skin to sexual maturity and causes abscesses of the affected region. It is usually found on the lower extremities, especially in the region of the heels.

*Filaria sanguinis hominis* is the name given to the *larvæ* (Fig. 574) of a worm, which occur in the blood and lymph of man,

and are about 0.35 mm. in length. The sexually mature worm is filiform, the male about 15 cm. long and the female 8 cm. It is called **Filaria Bancrofti** after its discoverer. The worm inhabits the lymph-vessels, particularly those of the scrotum and lower extremities, and may be present in large numbers. It causes lymph-stasis and inflammations which lead to *swellings of the lymph-glands* and to *elephantiasis-like thickening of the tissue*, associated with oedema and lymphangiectasis. Purulent inflammations, lymph-abscesses, buboes, chylous hydrocele, and chylous ascites may appear in consequence of its presence.

From the lymphatics of the limbs and scrotum the eggs and embryos (0.35 mm. long) (Fig. 574) pass into parts of the lymphatic system and into the blood, giving rise to hæmaturia, chyluria, and chylous diarrhoea. According to Manson and Scheube the filariæ are present in the blood taken from the skin only during the night; von Linstow explains this phenomenon as due to the fact that during sleep the peripheral vessels become dilated, and so permit the entrance of the filariæ, while the capillaries, being narrower during the day, do not permit such entrance. The hæmaturia is the result of the collection of embryos in the blood-vessels of the urinary tract. The chyluria and the chylous diarrhoea, on the other hand, are due to the obstruction by the parasites of the thoracic duct, thus causing a lymph-stasis which extends to the lymphatics of the bladder and intestine and there occasions the escape of lymph. According to Scheube the rupture of the lymphatics is also attended by a rupture of blood-vessels, so that blood becomes mixed with the lymph. The embryos may pass out from the urinary apparatus through the urine.

The distribution of the embryos is, according to Manson, accomplished by means of mosquitos, which take up the parasite during the act of blood-sucking. In the mosquitos they pass through a second stage of development and are then (James) after two or three weeks ready for the infection of a new host. Manson formerly held the opinion that they entered the water, and in a free condition were taken up in the water into the intestinal tract. The investigations of James, Low, Grassi, and Noè, who followed their development and migration in the body of mosquitos, make it seem probable that they are transmitted to a new host through the bite of the mosquito.

The *Filaria sanguinis* occurs, so far as is known, only in the tropics (Brazil, Egypt, Algiers, Madagascar, Zanzibar, Soudan, South China, Calcutta, Bahia, Guadeloupe).

*Mackenzie* estimated the number of filaria-embryos present in the total bulk of the blood of a case of hæmatochyluria closely studied by him at from thirty-six to forty millions. The patient died from empyema; during the disease the filariæ died.

In the **domestic animals** numerous *filaria-species* occur and inhabit different parts of the body. *Filaria papillosa* is a common parasite of the horse, donkey, and cattle; it lives in the serous cavities and reaches a length of from 5-18 cm. *Filaria hæmatica*, a worm 13-15 cm. long, inhabits the right heart and the pulmonary artery of the dog, and in this situation gives off its embryos to the blood-stream. It occurs particularly in America, China, and India.

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### III. Arthropoda.

#### 1. Arachnida.

§ 195. The parasites included among the **Arachnida** are chiefly epizoa, which either temporarily or permanently inhabit the skin. Only one species—*Pentastoma*—occurs in the larval form within the tissues. The most common parasites of this group belong to the *Mites* (*Acarina*). The *pentastoma* belongs to the family of *tongue-worms* (*Pentastomidæ* or *Linguatulidæ*).

(1) *Acarus scabiei* or *Sarcoptes hominis*, the itch-mite, is a parasitic mite the size of a pinhead with a turtle-shaped body, provided on the ventral surface both anteriorly and posteriorly with two pairs of legs, each of which is furnished with bristles (Fig. 575). The anterior pairs of legs extend out into pedicled clinging-discs. The same arrangement is found in the posterior two pairs in the male, while in the female both of the posterior pairs end in long bristles. Several bristles are also found along the border of the posterior portion of the body, while the back is studded with tooth-like knobs. The head is round and likewise set with bristles. The female is nearly double the size of the male.

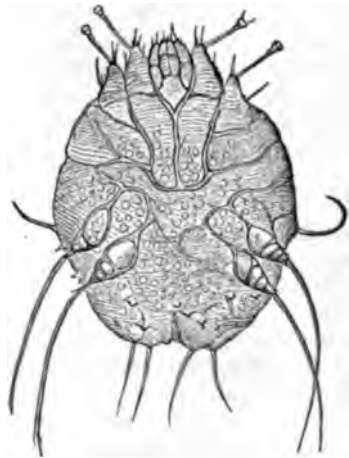


FIG. 575.—Female itch-mite, ventral surface.  $\times 40$ .

The mite lives in the epidermis (Fig. 576, *a*, *d*) in which it forms burrows, some of which are 10 cm. long.

In the burrows the female (*d*) lays the eggs, which develop *in situ* into the young itch-mites (*e*), which penetrate still deeper into the epidermis, and after repeated sheddings of their skins grow into sexually mature animals. The skin responds to the irritation produced by the

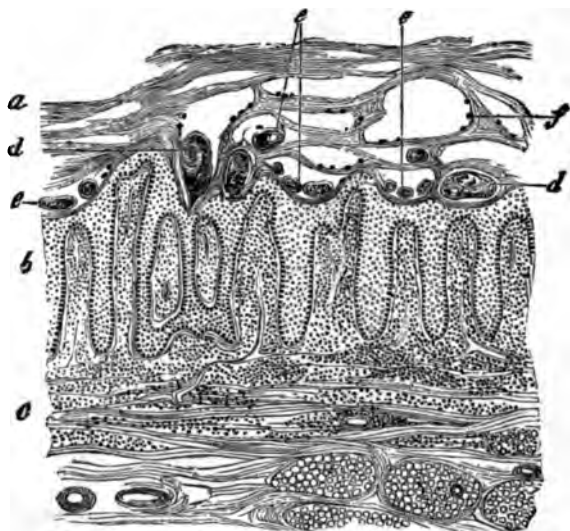


FIG. 576.—Scabies (alcohol, carmine). *a*, Horny layer of the epidermis, perforated by numerous burrows of the itch-mite; *b*, mucous layer, and papillary body, the latter greatly enlarged and infiltrated with cells; *c*, cutis infiltrated with cells; *d*, section through a fully developed itch-mite; *e*, eggs and embryos of different sizes; *f*, feces.  $\times 20$ .

presence of the mites by an increased production of epithelial cells (*a*) and inflammation (*c*). The latter is still further increased through the scratching of the spots which itch in consequence of the invasion.

2. **Leptus autumnalis**, the *harvest-mite* (Fig. 577) is the red-colored larva of a variety of *Trombididae*, which lives upon grasses and bushes and upon grain, and when occasion offers alights upon the skin of man, where it penetrates the epithelium and causes itching and inflammation.

3. **Demodex** or **Acarus folliculorum hominis** (Fig. 578) occurs either singly or in numbers in the hair-follicles of the face, as well as in the ducts of the sebaceous and Meibomian glands. Hausche found the demodex on the eyelashes in seventy-nine per cent., and Joers in sixty-four per cent. of the cases examined. Children under one year of age were free. The female is 0.4 mm. long, the male 0.3 mm. The eggs are deposited upon the shaft of the hair or upon any other portion of tissue, and develop after two sheddings into sexually mature animals which are found in the entrances to the hair-follicles and sebaceous glands, with their heads directed inward. The assumption that the demodex causes inflammation (acne, blepharitis acarica) is not supported (Joers, Hausche), since in spite of its presence in the great majority of cases signs of inflammation are wanting.

It is about 0.3 mm. long, and has on its anterior ventral surface four pairs of short thick feet. The head possesses a snout and two feelers.

4. **Ixodes ricinus**, the *wood-jack* or *wood-tick* (Fig. 579) is a fairly



large yellowish-brown member of the Arachnida belonging to the ticks. It has a black head provided with a sucking apparatus, and a very distensible leathery body. It is of common occurrence upon grass and bushes, and sometimes alights upon man or beast. By means of its sucking apparatus it draws blood from the skin and swells up to a very remarkable extent.

5. *Pentastoma denticulatum* is the larva of *Pentastoma tænoides*, a lancet-shaped animal belonging to the tongue-worms or *Pentastomidæ*. It inhabits the nasal, frontal, and maxillary cavities of various animals, especially of the dog, very rarely of man (Laudon) and occasions inflammations. The female of the mature animal is 50–80 mm. long, and anteriorly from 8–10 mm. broad; the male is 16–22 mm. long, and anteriorly from 3–4 mm. broad. The body consists of eighty-seven to ninety segments, the most anterior of which bear lateral segment-appendages, the pairs of limbs. The eggs, which are produced in very great numbers, are oval. The larva is 4–5 mm. long, 1.5 mm. broad, plump, flattened, and inhabits chiefly the liver, lung, or spleen, or more rarely the other organs of man and the herbivora. It occurs in the form of a small nodule encapsulated in connective tissue. The body consists of about fifty ring-shaped segments which are provided at the borders with spines (Fig. 580), and



FIG. 577.



FIG. 578.



FIG. 579.

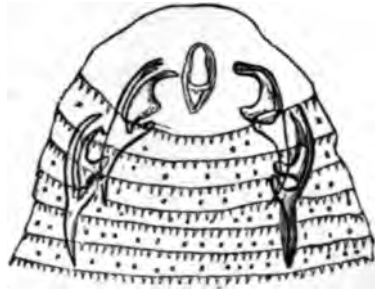


FIG. 580.

FIG. 577.—*Leptus autumnalis*. (After Küchenmeister and Zürn.)

FIG. 578.—*Acarus folliculorum hominis*. (After Peris.)  $\times 300$ .

FIG. 579.—*Ixodes ricinus*, sucked half full of blood.  $\times 2$ .

FIG. 580.—Cephalic end of *Pentastoma denticulatum*. (After Peris.)  $\times 40$ .

the cephalic end is provided with four hook-shaped feet. The eggs are taken in from the external world through the intestinal tract. The parasites set free in the intestine wander by means of a boring apparatus through the mesentery into the mesenteric lymph-glands, or penetrate directly into the blood-vessels, and are carried by the blood-stream

to the liver or even to the lungs, where after shedding they develop into the encysted larvæ. The larvæ may in their wanderings gain access to the nasal cavity of their host, and develop into mature animals, although the further development usually takes place only after their reception into a new host.

According to the published reports of *Tanaka* a small red mite occurs in great numbers in different parts of Japan during midsummer, and clinging firmly to the skin of man causes the so-called *Kedani-disease*, which is characterized by inflammation of

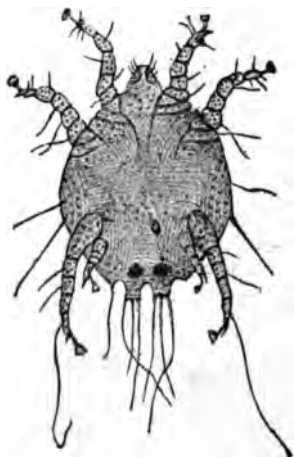


FIG. 581.



FIG. 582.

FIG. 581.—Male of *Dermatophagus communis* seen from the ventral side. (After Pütz.)  $\times 50$ .

FIG. 582.—Male of *Dermatoceptes communis*, seen from the ventral side. (After Pütz.)  $\times 50$ .

the skin and lymph-glands, with high fever, and often ends fatally. It is probable that these symptoms are due to secondary infections (proteus and streptococci) in the bites of the mite.

In the **domestic animals** living **mites** occur very frequently as parasites of the skin, and represent different species of various families.

*Sarcoptes hominis*, the *burrow-mite* or *itch-mite* of man is found also in horses and Neapolitan sheep. In addition still other different species of sarcoptes may be distinguished as parasites of the domestic animals—for example, *Sarcoptes equicavernarum* in dogs, hogs, sheep, and goats, and *Sarcoptes minor* in cats and rabbits.

*Dermatophagus*, the *derouring-mite* (Fig. 581), with a broad head, occurs in different animals, and different species may be accordingly distinguished. They live upon the cells of the epidermis and cause a desquamation of the skin.

*Dermatoceptes*, the *sucking-mite* (Fig. 582), with long narrow head, takes blood and lymph from the skin and causes inflammation. *Dermatoceptes communis* occurs in horses, cattle, and sheep. *Dermatoceptes cuniculi* is a parasite of the rabbit's ear.

*Symbiotes equi* of Gerlach is a mite which occurs chiefly upon the feet of the heavy English and Scotch horses, and causes a moist dermatitis, often incorrectly called *milanders*.

*Dermanyssus avium* is a long, red, blood-sucking mite, about 1 mm. long, and is often found upon birds.

Of the *tick family* there occur on dogs, cattle, and sheep different species of *Ixodes*, on pigeons *Argas reflexus*, and others. *Argas reflexus* can, according to D'Ajuto, occur also on man.

*Leptus autumnalis* occurs also on dogs and chickens.

Different species of *Demodex* occur in dogs and swine, and cause pustular eruptions.

*Pentastomata* occur also in cattle, sheep, and goats, and in certain regions are very common in the first named.

2. *Insecta*.

§ 196. The parasites belonging to the class of *Insecta* are for the greater part epizoa. In part they are but transient inhabitants of the skin, deriving from it their nourishment; in part they are permanent inhabitants and utilize the skin structures for the deposit of their eggs. Of the numerous species belonging to this class the following may be mentioned:

(1) ***Pediculus capitis***, the *head-louse* (Fig. 583), inhabits the hairy portions of the head, and derives its nourishment (i.e., blood) from the skin, by means of its feeding apparatus. Its eggs (nits) are barrel-shaped and white, and are attached to the hairs by means of a chitinous shell. The embryo hatches in about eight days. In consequence of the scratching induced by the itching there often arise inflammations of the skin, in particular eczemas, which are often relatively severe.

(2) ***Pediculus pubis***, the *felt* or *crab-louse* (Fig. 584), inhabits the hairy parts of the trunk and extremities. Its habits of life are the same as those of *Pediculus capitis*.

(3) ***Pediculus vestimentorum***, the *clothing* or *body-louse* (Fig. 585), lives in the wearing apparel, and lays its eggs in the same. It gets upon man to obtain its nourishment.

(4) ***Cimex lectularius***, the bedbug, dwells in beds, floors, closets, etc. During the night it gets upon man to suck blood. It causes wheals in the skin.

(5) ***Pulex irritans***, the *common flea*, also draws blood from the skin. At the point where it has sucked there is found a little punctate hæmor-



FIG. 583.



FIG. 584.



FIG. 585.

FIG. 583.—Female of *Pediculus capitis*, seen from the ventral surface. (Küchenmeister and Zörn.)  $\times 18$ .

FIG. 584.—Male of *Pediculus pubis*, seen from the ventral surface. (Küchenmeister and Zörn.)  $\times 18$ .

FIG. 585.—Female of *Pediculus vestimentorum*, seen from the ventral surface. (Küchenmeister and Zörn.)  $\times 9$ .

rhage. Occasionally it causes wheals and swellings. It lays its eggs in the cracks of floors, in sawdust, etc.

(6) ***Pulex penetrans***, the *sand flea*, occurs in South Africa in the sand. The female lays her eggs in the skin, thereby causing an intense inflammation.

(7) **Mosquitos** provided with stinging and sucking apparatus (*Culicidae* and *Tipulidae*), **horse-flies** (*Tabanidae*), and **flies** (*Stomoxys*) draw blood frequently from the skin of man. Various flies (*Æstridae* or biting

flies, *Muscidæ* or *blow-flies*) occasionally lay their eggs in the skin, in ulcers, or wounds, or in the accessible body-cavities, in consequence of which the maggots developing cause local destruction of tissue and inflammation (*myiasis*). Under certain conditions their larvæ may get into the intestinal tract with the food and there undergo further development (*myiasis intestinalis*). This is especially likely to occur when abnormal conditions which interfere with digestion are present in the stomach and intestine.

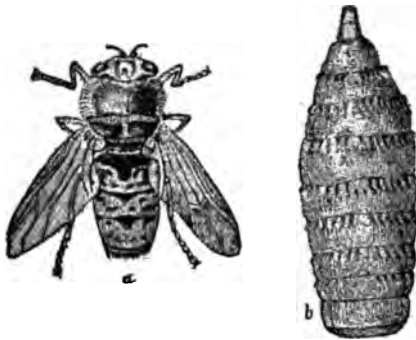


FIG. 586.—*Gastrophilus equi*. (After Brauer.) a, Male; b, larva.

The eggs of the *Muscidæ* (in Europe usually of *Sarcophila Wohlfarti*, in America of *Comptosia* or *Lucilia macellaria* and *Musca anthropophaga*), when laid upon the mucous membranes or in wounds, hatch after a few hours, and cause destruction of the neighboring soft parts through their efforts to obtain nourishment. In the auditory canal, nose, and antrum of Highmore, the bones may be laid bare (*myiasis mucosa*). In the course of about a week the larvæ leave the ulcers and pass into the pupa stage in the earth. The

*Estridæ* (in Europe, *Hypoderma bovis* and *Hypoderma Diana*; in America, *Dermatobia noxialis* or *Cuterebra cyaniventris*) lay their eggs upon wounds or in the intact skin. The larvæ, hatching very soon, penetrate into the cutis by means of their hooklets, and after several sheddings grow in from one to six months into larger larvæ about 2 cm. long. They cause, particularly in their later stages, painful swellings of the neighboring tissue (*myiasis æstrosa*).

Regarding the significance of different species of *Anopheles* as conveyers of malarial infection see § 182.

Parasites belonging to the *Muscidæ* and *Estridæ* play a more important rôle in the case of the **domestic animals** than in man; and the larvæ of the species of *Estrus* in particular occur as parasites in animals. For example, the larvæ of *Gastrophilus equi* (Fig. 586), *Gast. pecorum* and *Gast. hæmorrhoidalis* inhabit the stomach and adjacent portions of the intestinal tract of the horse, where they complete their development up to the pupa-stage, when they leave the animal.

*Estrus ovilis* lays its larvæ in the nasal cavities of sheep, whence they may wander, under certain conditions, into the frontal, nasal, and maxillary cavities, or even into the cranial cavity, and excite inflammation.

The larva of *Hypoderma* or *Estrus bovis* is 5–15 mm. long. It inhabits the skin and spinal canal of cattle, completing its development up to the pupa-stage, at which time it leaves the animal. According to *Schneidemühl* the larvæ do not always enter through the skin, but are more often taken in with the food, whereupon they penetrate through the wall of the œsophagus toward the skin and spinal canal. The latter follows from the fact that they are found in the wall of the œsophagus from October to January, and under the skin, on the other hand, from January to April.

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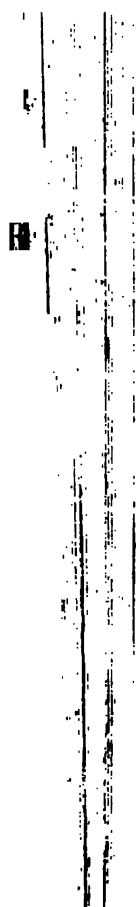
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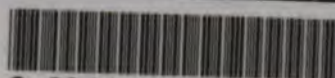
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